LONDON INSTITUTION FINSBURY CIRCUS

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVI. FEBRUARY 12, 1886. No. 4

EDWIN DUNKIN, F.R.S., President, in the Chair.

Rev. Charles Herbert Griffith, M.A., 1 College Grounds, Brighton;

John Hartnup, Liverpool Observatory, Bidston, Birkenhead;

Duncan Milligan, 21 Spencer Road, Wandsworth Common, S.W.;

Ole Möller, F.R.G.S., 8 Austin Friars, E.C., and 5 Shooter's Hill Road, Blackheath, S.E.;

Captain W. G. Morris, R.E.;

Rev. Charles J. Taylor, M.A., Toppesfield Rectory, Essex; and

Christopher Thwaites, Mem. Inst. C.E., Beccles, Suffolk;

were balloted for, and duly elected Fellows of the Society.

REPORT OF THE COUNCIL TO THE SIXTY-SIXTH ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society:—

	Compounders	Annual Subscribers	Non-resident	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1884 ...	227	378	1	3	609	49	1	659
Since elected	+5	+24	...	...	...	...	...	...
Deceased	−11	−13	−1	...	...	−1	...	...
Resigned	...	−10	...	...	...	...	...	...
Expelled	...	−2	...	...	...	...	...	...
Removals	+3	−3	...	...	...	...	...	...
December 31, 1885 ...	224	374	0	3	601	48	1	650

Mr. Common's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance at Bankers', Jan. 1, 1885	338	9	2			
„ in hand of Assistant Secretary on account of Turnor and Horrox Funds	8	7	11			
				346	17	1
Half-year's dividend on £7,500 Consols	109	4	5			
„ „ £5,700 New 3 per cent. Stock	83	0	2			
„ „ £7,500 Consols	108	15	0			
„ „ £5,700 New 3 per cent. Stock	82	13	0			
Dividends on £500 Metropolitan Stock	14	9	10			
Interest on money on deposit at Bankers'	1	17	0			
				399	19	5
Received on account of Subscriptions:						
Arrears	140	14	0			
263 Annual Contributions for 1885	552	6	0			
1 „ „ 1886	2	2	0			
35 Admission Fees	73	10	0			
29 First Contributions	43	1	0			
				811	13	0
8 Composition Fees				168	0	0
Sales of Publications:						
At Williams and Norgate's, 1884	38	10	8			
At Society's Rooms, 1885	26	18	0			
				65	8	8
Due to Assistant Secretary on Petty Cash Account, Dec. 31, 1885				13	3	7
				£1,805	1	9

Astronomical Society, from Dec. 31, 1884, to Dec. 31, 1885.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	225	0	0			
,, ,, for assistance in editing Society's Publications ...	50	0	0			
				275	0	0
Income Tax and House Duty				10	10	0
Fire Insurance				7	16	6
Printing	682	9	0			
Engraving and Lithography	30	7	4			
Computation of Ephemerides in *Monthly Notices* ...	50	0	0			
				762	16	4
Turnor and Horrox Funds: purchase of Books for Library	11	0	6			
Binding Books in Library	24	0	11			
Library Catalogue	55	5	0			
				90	6	5
House Expenses	33	2	4			
Wages	28	14	0			
Postage, &c.	62	0	6			
Carriage of Parcels, &c.	2	10	1			
Stationery and Office Expenses	2	7	8			
Expenses of Meetings	20	0	0			
Coals and Gas	52	3	11			
Repair of Gas Meter	5	6	0			
Care of Fire-extinguishing Apparatus	5	6	8			
Sundry Fittings and Repairs	7	17	5			
Sundries	3	3	6			
				222	12	1
Lee Fund				5	0	0
Mrs. Jackson Gwilt's Annuity				8	19	0
Bankers' Commissions on Cheques				0	2	4
Balance at Bankers', Dec. 31, 1885	395	2	7			
,, in hand of Assistant Secretary on account of Turnor and Horrox Fund	22	7	5			
				417	10	0
Paid Balance due to Assistant Secretary, Jan. 1, 1885, on Petty Cash account				4	9	1
				1,805	1	9

Audited and found correct, Jan. 6, 1886.

RICHARD INWARDS.
GEO. S. CRISWICK.
THOS. BUCKNEY.

Assets and Present Property of the Society, Jan. 1, 1886.

	£	s.	d.	£	s.	d.
Balance at Bankers', including an amount of £36 5*s.* 3*d.*, being the accumulated interest of the Lee Fund, Dec. 31, 1885	395	2	7			
„ in hand of Assistant Secretary on account of Turnor and Horrox Funds	22	7	5			
	417	10	0			
Less due to Assistant Secretary on Petty Cash account	13	3	7			
				404	6	5
Due on account of Subscriptions :						
3 Contributions of 4 years' standing ...	25	4	0			
20 „ 3 „ ...	126	0	0			
24 „ 2 „ ...	100	16	0			
58 „ 1 „ ...	118	18	0			
1 Admission Fee and First Contribution ...	3	3	0			
				374	1	0
Due from Messrs. Williams and Norgate for sales of Publications during 1885				29	15	7

£7,500 Consols, including the Lee Fund, the Turnor Fund, and the Horrox Memorial Fund.

£5,700 New 3 per cent. Stock, including Mrs. Jackson Gwilt's gift (£300).

£500 Metropolitan Board of Works Stock.

Astronomical and other Manuscripts, Books, Prints, Instruments, and Furniture.

Unsold Publications of the Society.

Report of the Auditors.

We, being the duly appointed Auditors, beg to lay before this Annual General Meeting of the Royal Astronomical Society the following Report :—

We have examined the Treasurer's account, and have found and certified the same to be correct. The receipts and expenditure for the past year are as stated in the Treasurer's account. The cash in hand on December 31, 1885, including the balance at the bankers', amounted to 417*l.* 10*s.* 0*d.*

The funded property is the same as at the end of last year.

The books, instruments, and other effects have been examined and found to be in a satisfactory condition so far as their safe keeping is concerned. A 6-inch Grubb telescope, without stand, has been received from the Transit of Venus Committee, to replace the $4\frac{6}{10}$ inch telescope, No. 29(3), which was lent to the Committee in 1882, and lost in the *City of Brussels*.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

(Signed) Richard Inwards.
Geo. S. Criswick.
Thomas Buckney.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXIX.	411	...
I. Part 2	43	...	XXX.	163	...
II. Part 1	53	...	XXXI.	145	1
II. Part 2	21	...	XXXII.	158	...
III. Part 1	66	1	XXXIII.	166	1
III. Part 2	85	1	XXXIV.	166	6
IV. Part 1	80	3	XXXV.	110	6
IV. Part 2	92	3	XXXVI.	199	10
V.	107	4	XXXVII. Part 1	340	4
VI.	126	3	XXXVII. Part 2	288	4
VII.	146	3	XXXVIII.	277	1
VIII.	128	3	XXXIX. Part 1	249	4
IX.	135	3	XXXIX. Part 2	254	4
X.	148	...	XL.	273	...
XI.	155	...	XLI.	421	...
XII.	162	...	XLII.	240	4
XIII.	165	1	XLIII.	248	1
XIV.	371	3	XLIV.	227	1
XV.	141	...	XLV.	264	2
XVI.	168	1	XLVI.	259	2
XVII.	149	2	XLVII. Part 1	3	...
XVIII.	148	...	XLVII. Part 2	21	...
XIX.	155	...	XLVII. Part 3	2	...
XX.	145	...	XLVII. Part 4	13	...
XXI. Part 1	314	...	XLVII. Part 5	13	...
XXI. Part 2	99	...	XLVII. Part 6	13	...
XXI. 1 & 2 (together)	63	1	XLVII.	254	7
XXII.	157	...	XLVIII. Part 1	347	6
XXIII.	152	...	XLVIII. Part 2	411	7
XXIV.	159	1	Index to *Memoirs*	645	1
XXV.	170	...			
XXVI.	174	2			
XXVII.	424	1			
XXVIII.	386	...			

Stock in hand of volumes of the *Monthly Notices* :—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	70	...	XXV.	7	...
II.	71	...	XXVI.	9	...
III.	...	...	XXVII.	3	...
IV.	...	...	XXVIII.	71	1
V.	...	...	XXIX.	52	...
VI.	38	...	XXX.	63	2
VII.	2	...	XXXI.	96	...
VIII.	139	2	XXXII.	117	5
IX.	22	3	XXXIII.	100	2
X.	175	1	XXXIV.	79	2
XI.	185	1	XXXV.	61	1
XII.	11	2	XXXVI.	32	1
XIII.	158	3	XXXVII.	38	3
XIV.	109	3	XXXVIII.	102	2
XV.	128	2	XXXIX.	100	1
XVI.	107	2	XL.	113	3
XVII.	136	1	XLI.	114	3
XVIII.	166	...	XLII.	122	5
XIX.	56	...	XLIII.	126	3
XX.	34	...	XLIV.	130	8
XXI.	17	...	XLV.	137	5
XXII.	32	...	Index to *Monthly Notices*	568	1
XXIII.	19	...			
XXIV.	23	...			

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to XLV. no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.

No. 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection:—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3) Equatoreal stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length; with iron stand and also Ys for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

No. 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.

„ 52. (26) Dipping needle, by Robinson.

„ 53. (27) Compass needle, mounted for variation.

No. 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.

„ 55. (29) Box of magnetic apparatus.

„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.

„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.

„ 58. (32) Plane 2⅜-inch speculum, artificial horizon, and stand.

„ 59. (33) 2½-inch circular level horizon, by Dollond.

„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.

„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.

„ 62. (36) A pantagraph.

„ 63. (37) A noddy.

„ 64. (38) A small Galilean telescope with object-glass of rock crystal.

„ 65. (39) Five levels.

„ 66. (40) 18-inch celestial globe.

„ 67. (41) Varley stand for telescope.

„ 69. (43) Telescope, with object-glass of rock crystal.

„ 70. Portable Equatorial stand (lost in the "City of Brussels").

„ 71. Portable altazimuth tripod.

„ 72. Four polarimeters.

„ 74. Registering spectroscope, with one large prism.

„ 76. Two five-prism direct-vision spectroscopes.

„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.

„ 79. Spectroscope.

„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.

„ 81. A back-staff, or Davis' quadrant.

„ 82. A nocturnal or star dial.

„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.

„ 84. A Hollis observing chair.

„ 85. Double image micrometer, by Troughton and Simms.

„ 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

No. 87. $3\frac{1}{4}$-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum with 5-foot brass suspension rod, working on knife edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, $5\frac{3}{4}$ inches in diameter.
„ 91. Astronomical time watchcase, by Professor Chevallier.
„ 92. 2-foot protractor, with two moveable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2 feet 6 inch navy telescope with object-glass $2\frac{1}{2}$ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer & Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatoreal sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Small brass astrolabe.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 116. A pair of 18-inch globes.
„ 117, „ 118. Two old sun dials.

No. 119. Specimens of rulings on speculum metal, by Prof. W. A. Rogers, presented by H. J. Chaney, Esq.
„ 120. A 6-prism spectroscope, by Browning, presented by J. D. Perrins, Esq.
„ 121. Improved maximum and minimum thermometer, presented by E. J. Spitta, Esq.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel, presented by R. J. Ryle, Esq.
„ 123. A 6-inch refracting telescope, by Grubb, with 6 eyepieces, solar diagonal, 2 dark wedges, &c. (To replace telescope 29 (3), lost.)

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 22. The *Matthew* equatoreal, to Mr. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 29. (3) Three micrometers, to Mr. E. Ristori.
„ 30. (4) $3\frac{1}{4}$-inch equatoreal and stand, to Mr. H. Sadler.
„ 31. (5) $2\frac{3}{4}$-inch telescope and stand, to Mr. E. Ristori.
„ 34. (8) Transit instrument, to Prof. C. Pritchard.
„ 69. (43) Telescope, with rock-crystal object-glass, to Dr. W. Huggins.
„ 74. Registering spectroscope, to Mr. E. B. Knobel.
„ 120. 6-prism spectroscope, to Lieut.-Col. G. L. Tupman.
„ 123. 6-inch telescope, to Lord McLaren.

The Gold Medal.

The Council have awarded the Society's Gold Medal jointly to Prof. E. C. Pickering and Prof. Charles Pritchard for their photometric researches. The President will lay before the Society the grounds upon which the award has been founded.

Publications of the Society.

Vol. XLVIII., Part 2, of the *Memoirs* has been published during the year. It contains the following papers :—

Fourth Catalogue of Micrometrical Measures of Double Stars, made at the Temple Observatory, Rugby. By G. M. Seabroke.

On the Relative Proper Motions of 40 Stars in the *Pleiades*, determined from Micrometric and Meridional Observations. By Prof. C. Pritchard.

Observations of *Mars* at the Opposition of 1884. By E. B. Knobel.

On the Corrections required by Hansen's "Tables de la Lune." By E. Neison.

Sur une inégalité lunaire à longue période. By M. C. Gogou.

Library Catalogue.

A Catalogue of the Library has been prepared by the Assistant-Secretary, which is now in the press, and will shortly be in the hands of Fellows.

Lunar Computations.

The Royal Society have granted to the Secretary, as representing the Council, the sum of 320*l.* from the Government Grant Fund for the purpose of comparing Greenwich Lunar Observations 1847 to 1861 with Hansen's "Tables de la Lune." The computations are being made under the superintendence of Mr. Hind, and they will probably be completed before the next Annual Report.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associate during the past year:—

Fellows:—Admiral H. W. Bayfield.
Rev. R. H. Blair.
Sir F. J. O. Evans.
F. T. Hall.
Major-General J. C. Hannyngton.
John Hartnup.
E. W. Jones.
William Ladd.
James Lawson.
James McDowell.
Nicholas Martindale.
Colonel Charles Ratcliff.
Rev. William Read.
The Earl of Shaftesbury.
Joseph Sidebotham.
Rev. T. A. Southwood.
Marcus Warburg.
John Watson.
Rev. T. W. Webb.
William Wray.
Colonel William Yolland.

Associate:—Thomas Clausen.

Admiral Henry Wolsey Bayfield was born in the year 1795. At the early age of eleven he entered the Royal Navy on board the *Beagle* sloop as a first-class volunteer. After having been employed on several naval stations between 1806 and 1813, he was in 1814 attached to the squadron stationed in Canada during the latter part of the second American war. He obtained his first commission on March 20, 1815, and soon after he became permanently employed on the survey in that colony, in which he became distinguished as a most valuable scientific officer. From September, 1816, to the date of his retirement from active service in 1856, on his promotion to the rank of rear-admiral, he was continuously engaged on the survey of the coasts and rivers of Canada and other British possessions in North America,

including the lakes Ontario, Huron, and Erie, the river St. Lawrence, and the coast of Labrador. Captain Bayfield, in times of leisure from his surveying duties, was accustomed to observe occultations of stars by the Moon, the phenomena of *Jupiter's* satellites, &c. Some of these observations are recorded in the *Monthly Notices*. At Quebec he observed the transit of *Mercury* of May 5, 1832, with one of Jones's $3\frac{1}{2}$-foot achromatic refractors. In 1848 he communicated to the Society an excellent series of observed occultations of stars by the Moon and phenomena of *Jupiter's* satellites made at his residence at Charlottetown, Prince Edward Island, together with the resulting determinations of the longitude of his residence, from which he deduced the longitude of the Observatory Bastion at Quebec. The reductions appear to have been made with some care, after applying to the tabular places of the Moon corrections furnished by the Astronomer Royal.

Admiral Bayfield attained the rank of Post-Captain in 1834, Rear-Admiral in 1856, and Admiral in 1867. His death took place at Charlottetown on February 10, 1885, in the ninetieth year of his age. He was at the time of his decease the senior Fellow of the Society, and the last of the "non-resident" Fellows, having been elected on May 11, 1827.

Captain Sir Frederick J. O. Evans, R.N., K.C.B., F.R.S., entered the Royal Navy in the year 1828, and served in H.M. ships *Rose* and *Winchester*, on the North American station, until 1833, when he was transferred to H.M. surveying-vessel *Thunder*, Commander Richard Owen, and was employed until 1836 in surveying operations in various parts of the West Indies.

It was in this ship, and under the guidance of her able captain, that he imbibed those scientific tastes which formed his character later in life, and laid the foundation of a career of usefulness, uninterrupted to its close, and which has perhaps rarely found a parallel in the naval profession.

Mr. Evans subsequently served in the *Caledonia*, the flagship in the Mediterranean, the *Asia*, the *Rapid*, the *Rolla*, the *Dido*, and *Wolverene*, of which two latter ships he was acting master. He was confirmed in that rank in 1841, and was then appointed to H.M.S. *Fly*, Captain F. P. Blackwood, fitting for special exploring and surveying service in Australia and New Guinea, where he was continuously employed until 1846. He took a very leading part in the examination of the Coral Sea, the Barrier Reefs of Australia, Torres Strait, and the neighbouring shores of New Guinea, regions then comparativeiy unknown. After a short period of surveying service on the home coasts, Evans was appointed to the *Acheron*, under the late Admiral Stokes, and was engaged until 1851 in exploring and surveying the coasts of the then young colony of New Zealand; in both these important enterprises he took a very conspicuous part, and gained for himself the reputation of a skilful and scientific surveying officer, second to none in the profession.

During the Russian War Evans was employed in the Baltic on special reconnoitring service, and was attached to various ships of the fleet, taking an active part in the operations against Bomarsund and among the Aland Isles, for which he was mentioned in gazetted despatches.

It may be truly said that for many years of his life Evans was a zealous contributor to magnetic science. He had already begun to make observations of the three magnetic elements whilst employed on hydrographic work in H.M. ships *Fly* and *Acheron* in the Australian Colonies and New Zealand, between the years 1842 and 1851; but it was not until 1855, when he became Superintendent of the Compass Department of the Royal Navy that he was able to devote himself entirely to the magnetism of iron ships, a subject which was then growing yearly in importance, from the increasing amount of iron used in fitting as well as construction even before iron plating had brought about an actual crisis.

Sagaciously foreseeing the important part the science of magnetism was destined to play in the Navy, then being revolutionised by the change from wood to iron, he devoted his whole energies to the study of the subject until he had made himself completely master of it.

In 1865 Capt. Evans was appointed Chief Assistant to the Hydrographer, retaining his position as head of the magnetic department; this post he continued to hold until the early part of 1874, when a vacancy occurring in the Hydrographership of the Admiralty he was selected to fill it, and continued to do so with equal ability and conscientiousness until within a little more than a year of his death.

From the time of his first appointment in 1855 as Chief of the Admiralty Compass Department until his death Capt. Evans (in happy co-operation during a great part of the time with that great mathematical genius Archibald Smith) devoted himself heart and soul to the solution of what was really a question of life and death to the British Navy, and indeed to seafaring people all over the world.. The question was whether it was possible so to deal with the disturbing element of iron, then entering largely into the construction of ships of all kinds, as to prevent the time-honoured compass from becoming a useless toy, or even a misleading guide. Now that the difficulty has been grappled with and conquered, we have half learned to forget the magnitude of the peril. But for the scientific and practical progress due to the labours of Capt. Evans and Archibald Smith we might almost with advantage have thrown all our compasses overboard. The attraction due partly to the inherent and partly to the induced magnetism of iron ships, and especially of plated ships, was so violent as to induce in some vessels, in certain positions, errors of two, three, or four points of compass indication. Something had been done to explain the causes of the mischief and to suggest palliatives. Famous old Flinders, at the

beginning of the century, had spelt out the mystery so far as it was disclosed by the wooden ships of his time, but he had to deal with comparatively minute errors due to induction alone, and was never brought face to face with the stupendous difficulty which iron shipbuilding and iron ship-plating afterwards created. Sir George Airy had done good and sound work in the earlier days of iron, but much more was needed to overcome the serious trouble which the newer types of mercantile and still more of naval vessels threatened to bring upon us.

It was at this critical epoch that Capt. Evans and Archibald Smith began to work together. Years of experimental labour and mathematical research went to the production of the "Admiralty Manual on Deviations of the Compass"—a book perhaps as perfect in its kind as a book could be. It is hard to do justice to the elegance of the mathematical handling, and, above all, to the happiness of the graphic methods which are found in the Manual, without seeming to indulge in extravagant laudation.

The various steps of Evans's work may thus be stated :—

In 1858 a Chart of Curves of Equal Magnetic Declination, compiled by him for that epoch, was published by the Admiralty. This chart appeared most opportunely, for, with compass errors growing in amount and complexity, the mariner was by means of it enabled to ascertain in any part of the navigable world how far his compass deviated from the magnetic north.

In 1859 he read a paper on the magnetism of iron ships at the Royal United Service Institution. This was a valuable *résumé* of all that had been hitherto done in order to obtain a knowledge of the magnetism of iron ships and the treatment of their compasses. He also communicated some results of Archibald Smith's method of analysis as applied to the errors of the compass found in H.M. ships.

Evans's next paper consisted of a Report to the Hydrographer of the Admiralty on Compass Deviations in the Royal Navy. It treated of the magnetic character of the various iron ships in the Navy, and also of the *Great Eastern* steamship. The results of this paper were (1) to show the best direction for building an iron ship ; (2) the best position for placing her compass ; (3) the various sources of error affecting a compass under favourable conditions. This report was communicated to the Royal Society, and published in their "Transactions" in 1860.

In 1861 he read a paper of similar import before the Institute of Naval Architects.

Reference has already been made to his work on the *Great Eastern*, and an important result of it was the experimental investigation which he was led to make as to the cause of the abnormal errors of the compasses in that vessel, proceeding from the application of Airy's system of magnet and soft-iron correctors when long single-compass needles are used.

With Evans principally as an experimentalist and Archibald Smith as the mathematician, a valuable paper on the proper

length and arrangement of the needles on a compass card, together with exact information as to the proper arrangement of magnet and soft-iron correctors with respect to it, was presented to the Royal Society in 1861, being the result of the joint work of those ardent investigators into the compass question in iron ships.

Commencing with this latter paper, we find Evans and Smith, as we have said above, generally working together, and under their joint editorship there appeared in 1862 the first edition of the "Admiralty Manual for Deviations of the Compass." The introduction, however, of armour-plated ships soon rendered a new edition necessary, and in 1863 it was published. This work was again revised in 1869, and became the text-book of the world on the important question of the deviations of the compass in iron ships of whatever form, being translated into all the principal European languages.

In 1865 Evans and Smith produced another important paper on the "Magnetic Character of the Armour-plated Ships of the Royal Navy," which was published in the "Phil. Trans. Roy. Soc."

It was only natural that a joint editor of the "Admiralty Manual for Deviations of the Compass," who knew the difficulties of that work for his fellow-seamen, should wish to present the subject, on which he had worked so long, in an elementary form more suitable to their every-day requirements. Evans therefore, in 1870, published his "Elementary Manual for Deviations of the Compass," a work which has been very well received by the nautical world, and has been translated into various European languages.

With the exception of some papers read at certain meetings of the British Association, and two lectures read at the Royal United Service Institution in 1865 and 1872, Evans subsequently relaxed his personal investigations into the magnetism of iron ships, and turned more to terrestrial magnetism.

Thus, in 1872 he contributed a paper to the Royal Society, on the magnetic declination in the British Islands, and compiled the magnetical instructions for the voyage of H.M.S. *Challenger*, being again assisted in this, and for the last time, by his old fellow-labourer, Archibald Smith.

Lastly, in 1878, Evans read an able and instructive lecture, on the magnetism of the earth, before the Geographical Society, showing the distribution and direction of the earth's magnetic force and the changes in its elements as then known.

Captain Evans was elected a Fellow of the Royal Society in 1862. He sat for many years on its Council, and was more than once a Vice-President. He was also a Fellow of the Royal Astronomical and Geographical Societies; he served for many years as member of the Meteorological Committee of the Royal Society, and on the change in the constitution of that body became a member of its Council.

In recognition of his public services the Companionship of the Bath was conferred upon him in 1873, and in 1881 he was advanced to Knight-Commandership of the same order.

Sir Frederick Evans's last public service after his retirement from the Admiralty in 1884 was as the British Delegate at the Congress of Washington for the establishment of a prime meridian and questions kindred to it.

He died on December 20, 1885, in his 71st year.

He was elected a Fellow of this Society on December 12, 1856.

Major-General John Caulfield Hannyngton, Fellow of the Institute of Actuaries, was born in Dungannon, Co. Tyrone, on March 7, 1807. He entered the army as a cadet in 1825, and served in the 24th Regiment of Native Infantry until, on the suppression of the Colekan insurrection, he received a political appointment, and was placed in charge of the Mànbhoom Division on the southern frontier, where he remained until, in 1842, he was selected to fill the highest judicial position on the frontier, that of Judicial Commissioner.

On his promotion to the rank of Lieut.-Colonel, in 1856, he returned to regimental duty, in accordance with the regulations of the Service, and took command of the 63rd B.N.I. He was with his regiment at Berhampore at the time of the Mutiny in 1857, and was for some time in command of the station. The 63rd did not mutiny, but were disarmed.

The reputation which Colonel Hannyngton had acquired led very shortly to his transfer to the Military Finance Department, and finally to his appointment as Military Auditor-General, in which office he remained until the close of his active military career in 1861, when he retired on his pension.

Throughout nearly the whole of his service General Hannyngton sedulously watched over the affairs of the Bengal Military and Orphan Funds, and placed his knowledge, his skill, and his labour gratuitously at the disposal of the directors of those splendid institutions. He was, in fact, their most able consulting actuary. True it is that to his sympathetic nature it was always a labour of love to work for the widow and orphan; but only those who know the responsibilities, anxieties, and arduous nature of the actuarial duties connected with institutions of the magnitude of the Bengal Military and Orphan Funds can duly appreciate the self-sacrificing devotion of one who voluntarily and gratuitously undertook such onerous duties in addition to his daily official work in the administration of justice in a large province.

After his retirement the services of General Hannyngton, as a skilful actuary, were on several occasions called into requisition by the Secretary of State for India with regard to the affairs of the Staff Corps and on other matters. To him are due also the whole of the calculations and arrangements under which the Government took over the Annuity and Civil Funds of the

Civil Services of Bengal, Madras, and Bombay, involving questions amounting to millions of pounds sterling between the Government and the members of those distinguished Services, their widows and children. The last of these laborious undertakings, for which, from his knowledge of India and the circumstances of the cases, he was so pre-eminently qualified, had been but very recently completed when he died.

In 1872 he was appointed Assistant Secretary in the Finance Department of the India Office, and remained in that appointment to the end of his long life of zealous, indefatigable, eminently useful, and well-nigh unique service. He may most truly be said to have died in harness.

General Hannyngton's scholarly and scientific attainments were great and varied. To unusual mathematical acquirements as applied to astronomy and navigation were united actuarial abilities of a very high order. He was a good scholar in Oriental languages, more especially in Bengalee. By practice during a long series of years in the performance of his judicial duties he had made himself an expert shorthand writer. The value of Thoman's arithmometer was very early recognised by him, and he was the first to avail himself of it in the calculation of life contingencies. To his intelligence and mathematical power is due the invention of a very ingenious and useful slide-rule. His best known and largest work is a table of Haversines, natural and logarithmic, used in computing distances for the "Nautical Almanac." It was printed by the Admiralty, and is a fitting and enduring monument of his patient and persevering industry.

General Hannyngton was a truly pious, simple-minded, Christian gentleman, trusted, respected, and beloved by all who knew him.

He was elected a Fellow of this Society, 1875, March 12.

John Hartnup was born at Hurst Green, in Sussex, on January 7, 1806. His first astronomical work of importance was performed at Mr., afterwards Lord, Wrottesley's private observatory at Blackheath, where he was employed as assistant. The part taken by Mr. Hartnup in the observations of the Wrottesley Catalogue of Stars is referred to in the Society's *Monthly Notices*, No. 1, Vol. iv. He was subsequently engaged as a supernumerary at the Royal Observatory, Greenwich, and afterwards became Assistant Secretary to the Royal Astronomical Society. The results of a series of observations made by Mr. Hartnup with a sextant and pocket chronometer for determining the latitude and longitude of the Society's apartments at Somerset House are given in the *Monthly Notices*, No. 2, Vol. vi. In November, 1843, Mr. Hartnup was appointed Director of the Liverpool Observatory. A few words as to the objects of this establishment may perhaps not be out of place.

Between the years 1834 and 1838 urgent requests were

frequently made by officers in the Royal Navy and in the Mercantile Marine, astronomers, and various scientific men, for the establishment of a Nautical Observatory at Liverpool. In 1837 a memorial was presented to the Corporation by the British Association for the Advancement of Science. The memorial drew attention to the fact that no one was responsible for giving correct time to the port; that chronometer-makers could not be trusted to make the necessary astronomical observations themselves, as they had been known to differ from each other as much as two minutes in the Greenwich mean time, and that such errors must be dangerous to vessels leaving the port. A committee of the Town Council appointed to take the matter into consideration reported that the means for giving accurate time to the port did not exist, and that chronometers were sent to sea with various sources of error. The chief objects, then, of the establishment of an observatory in Liverpool were the communication of accurate time to the port and the rating of chronometers.

The great differences frequently found to exist between the sea and shore rates of chronometers was a subject which appeared enveloped in mystery. Mr. Hartnup found change of temperature to be the chief cause of these changes of rate. No. 8, vol. ix., of the Society's *Monthly Notices* contains a paper by Mr. Hartnup on an improved form of compensation balance. This balance is practically perfect in its action, as chronometers to which it is applied maintain very nearly the same rate in extremes of heat and cold and in the middle temperature. It is, however, not nearly so strong as the ordinary form, is much more difficult to make and also to adjust, and is liable to be injured by unskilful hands. Although the architect availed himself of the advice of the best authorities of that day on the construction of the building, no provision was at first made for controlling the temperature in the chronometer-room at the Liverpool Observatory. Limited arrangements for this purpose were afterwards made at Mr. Hartnup's request. The Report for 1854 of the British Association for the Advancement of Science contains a paper by Mr. Hartnup on the variation in the rates of chronometers, and tables are given showing the change in the daily rate of each of one hundred chronometers caused by changing the temperature from 40 to 60, from 60 to 80, and from 50 to 80 degrees Fahrenheit. In consequence of Mr. Hartnup's reports on the importance of testing chronometers before they are used at sea the Mersey Docks and Harbour Board extended and improved the arrangements for testing these instruments, and soon after the removal of the Observatory to Bidston, permission was given by the Board to establish a system of testing chronometers in the two extremes and middle temperature to which ships are generally exposed at sea. A careful examination of the results obtained from the tests of upwards of a thousand chronometers in the three definite temperatures of 55, 70, and 85 degrees Fahrenheit showed:—

1. That there was a definite temperature peculiar to each chronometer, in which it went faster than in any other temperature.
2. As the number of degrees above or below the temperature of maximum gaining rate increased, the chronometer lost in a rapidly increasing ratio.
3. Rates calculated on the assumption that the rate changes directly as the square of the number of degrees from the temperature of maximum gaining rate agreed closely with rates obtained from observation.

In his Report for 1872 to the Marine Committee of the Mersey Docks and Harbour Board, Mr. Hartnup gives a formula for calculating the correction due to thermal error, for any temperature of a chronometer whose rate has been determined by observation in the three definite temperatures of 55, 70, and 85 degrees Fahrenheit. An example showing the advantage of applying such corrections to the rates of two chronometers during a voyage from Liverpool to Calcutta is given in No. 2, vol. xxxv., of the Society's *Monthly Notices*. Vol. iii. of the "Dun Echt Observatory Publications," recently issued by the Earl of Crawford and Balcarres, contains a detailed account of the determination of the temperature corrections of the fifty chronometers employed on his expedition to Mauritius for the observation of the Transit of Venus in 1874. These chronometers were tested at the Liverpool Observatory both before and after the expedition, and Mr. Hartnup's formula was used in the calculation of the corrections for thermal error. In 1877 the Directors of the Pacific Steam Navigation Company ordered the chronometers belonging to their ships to be sent to the Liverpool Observatory to be rated. The notices as to the work at the Liverpool Observatory contained in the annual Reports of the Council of the Society show the careful attention given by Mr. Hartnup to the performance of these chronometers and the accuracy with which Greenwich time can be carried on at sea with chronometers of average quality, when their thermal errors are determined at an observatory provided with efficient apparatus for the purpose, and the corrections due to change of temperature are applied to the rates.

The Liverpool Observatory is provided with an equatoreal of great firmness and steadiness, and Mr. Hartnup's early reports show his ability in the use of this instrument. The results of observations of comets and of several of the minor planets were communicated to the Society, and published in the *Monthly Notices*. The chronometric work, however, gradually became heavier. A large number of chronometers were deposited at the Observatory for the purpose of being rated, and Mr. Hartnup considered the investigation of their performance under varying conditions the most important work to which he could devote his energies and the means at his disposal.

An excellent method of controlling clocks by electric currents was first adopted at the Liverpool Observatory. A paper by Mr. Hartnup on this subject is published in the Report for 1857 of the British Association for the Advancement of Science.

Mr. Hartnup resigned the directorship of the Liverpool Observatory in May, 1885. His health had been failing for some time, and on his retirement he took up his residence in London, chiefly with the view of obtaining medical advice. He died suddenly in London on October 20, 1885.

Enough has been said to show the great amount of labour bestowed by Mr. Hartnup on the subject of marine chronometry. The highest authorities have spoken in strong terms of the utility of the work done at the Liverpool Observatory in testing chronometers for the mercantile marine. Sir G. B. Airy, K.C.B., when Astronomer Royal, repeatedly alluded to the importance of this work. Mr. Hartnup was elected a Fellow of the Royal Astronomical Society on February 14, 1845.

William Ladd was born at Deal in 1815, whence he came to London at the age of 14. Mr. Ladd was well known in scientific and commercial circles for his efforts in aiding research, for during the decade extending from 1860 to 1870 he took a very prominent part in introducing electricity into practical utility. Nor was his interest in this line confined merely to any particular branch of the science, for we find him at one time in correspondence with Prof. Reis, who may be said to have made the earliest efforts towards recording the sound of the human voice transmitted over long distances. A letter is still extant in which Prof. Reis explains to Mr. Ladd his views upon this question, and the partial success that attended his efforts. Mr. Ladd was well known as the constructor of some of the largest induction coils and electrical apparatus, manufactured under his supervision at his premises in Beak Street, Regent Street.

In 1867 Mr. Ladd brought forward a dynamo machine, which in many respects showed a marked improvement on the previous dynamos of Siemens, Varley, and Wilde, and whereby many of the then existing difficulties in the way of constructing dynamos for practical and commercial use were removed. Somewhat later, in the year 1878, Mr. Ladd was instrumental in introducing into this country the Wallace-Farmer system of electric lighting from America, where it had met with considerable success. The dynamos and arc lamps employed on this system underwent considerable improvement at Mr. Ladd's hands; and one of the earliest installations of electric lighting afforded to the public was made under Mr. Ladd's supervision on the above system at the Liverpool Street terminus of the Great Eastern Railway.

Mr. Ladd was from the time of its formation a director of the Anglo-American Brush Electric Light Corporation (Limited),

and also of the Electrical Power Storage Company, and he took an active interest in the administration of these companies until almost the day of his death.

Mr. Ladd was of a kind and loving disposition, always ready to help others with advice and means. He died after a long and painful illness on April 16, 1885.

He was elected a Fellow of this Society on April 12, 1867.

James Lawson was born in London on January 28, 1847. Left an orphan when very young, he early determined to go to sea, and the profession he selected was throughout his life one for which he had a most ardent love. After several years spent on different vessels he, in 1870, joined the Royal Mail Company as fifth officer. In this service he distinguished himself by his thorough capabilities as a seaman, and by possessing an immense amount of knowledge of the physical geography of the sea, and in eight years he rose to the rank of captain. On February 15, 1885, in severe weather, he left New York, with an excellent staff of officers and a good crew, in command of the ill-fated steamship the *Humber*. Nothing has ever been heard of the vessel since, and she is supposed to have foundered.

He was elected a Fellow of this Society, 1883, May 11.

James McDowell was born at Ballymacarow, co. Down, Ireland. He was a graduate both of Trinity College, Dublin, and Pembroke College, Cambridge, and in both universities he earned high distinction in many ways. At Dublin he five times obtained first-class honours in science, besides the first silver medal in mathematics at the degree examination. At Cambridge, in spite of the disadvantages arising from very bad health, he took the highest places in his college both in classics and mathematics, and graduated as seventeenth wrangler. Since the period of taking his degrees, his time has been principally devoted to private tuition, and many past and present members of the University of Cambridge will grieve to hear of the death of their tried and able tutor. In 1863 he published "Exercises on Euclid and in Modern Geometry," which was one of the first Cambridge books in which such subjects as harmonic and anharmonic pencils and ranges, radical axes and centres, involution, poles and polars, and reciprocal polars were considered in an elementary geometrical manner. Mr. McDowell treated these subjects as much as possible by Euclidean methods, so as to render the book acceptable to those who were only familiar with the ancient geometry. He was also one of the original editors of the *Messenger of Mathematics* at its foundation in 1862. In 1867 he published a Mechanics for use in the elementary examinations of the University.

He died at Cambridge, on March 17, 1885, leaving a widow and four children.

He was elected a Fellow of this Society, January 10, 1862.

Nicholas Martindale (youngest son of N. Martindale) was born in Liverpool, July 23, 1822, and resided in that neighbourhood for many years.

He was greatly interested in all scientific pursuits, and particularly in astronomy, to which at one period of his life he devoted much of his time, possessing in his observatory at Holmfield Street, Liverpool, a very fine telescope by Alvan Clark.

After his marriage, in 1863, he went to live in the neighbourhood of London, where he remained till within a few years of his death, when he returned to the North and died at Southport, April 6th, 1885, after many years of delicate health, sincerely regretted by all who knew him.

He was elected a Fellow of this Society, 1862, April 11.

Colonel Charles Ratcliff, formerly of Wyddington, Edgbaston, near Birmingham, was a younger son of John Ratcliff, Esq., of Birmingham, and brother of the late Sir John Ratcliff, who was mayor of Birmingham, and who received the honour of knighthood on the occasion of the visit of the Queen and Prince Consort to open Aston Park in 1858. He was called to the Bar at Lincoln's Inn in 1848, but never followed the legal profession actively, being a director of the Birmingham Banking Company, Limited. He kept some terms at Downing College, Cambridge, of which he was M.A. He was a Fellow of the Society of Antiquaries and a member of the Athenæum and National and Conservative Clubs. He also was a "Goldsmith," and as such was a freeman of the City of London. In 1867 he became Lieut.-Colonel of the Birmingham Rifle Volunteer Corps, but resigned in 1871. He was presented with a sword by the officers and privates of that corps. He took an active interest in the promotion and management of reformatory and industrial schools, a work in which he was associated with Lord Norton, Mr. M. Davenport Hill, the Rev. Sidney Turner, and others. The first Reformatory Conference, held in Birmingham in 1851, was largely promoted by Colonel Ratcliff, who acted as one of its secretaries, attending all its meetings from the first. He acted to the very last as secretary and treasurer to the Saltley Reformatory Institution, near Birmingham. He was appointed to the colonelcy of the Surrey Rifles, and on retiring he was allowed to retain his rank.

He took an active part in the first Social Science meeting at Birmingham in 1857, when he had Lord Brougham (the President) as his guest.

He died at Matlock Bank on August 28, 1885, and was buried at Edgbaston, Lord Leigh, Lord Norton, and many of his public and private friends attending.

Colonel Ratcliff married, in 1875, Helen, daughter of the late Sir William Jardine, Bart., F.R.S., who survives him without issue.

He was elected a Fellow of this Society, 1874, May 8.

Anthony Ashley Cooper, Earl of Shaftesbury, was born on April 28, 1801. He was educated at Christ Church, Oxford, where he obtained a first class in classics in 1822, graduated M.A. in 1832, and was created D.C.L. in 1841. Lord Shaftesbury's great position as a philanthropist has been so fully dealt with elsewhere that it is unnecessary to call lengthened attention to it here. In him has passed away the most eminent social reformer of the present century. It is not too much to say that he had acquired a world-wide fame as a philanthropist, and that his name is inextricably interwoven with many of the most humane movements of two generations. Pre-eminently the friend of the poor, the degraded, and the outcast, his generous sympathies and his ceaseless efforts on behalf of the classes in whom he took so deep an interest have given him a high place in the illustrious roll of benevolent Englishmen. It is interesting, and perhaps not a little singular, to note that one of the most steadfast and powerful friends which the humbler classes have ever had, as well as one of the most trusted, did not belong to their own order of the commonalty, but to the privileged order of the aristocracy.

Lord Shaftesbury never engaged particularly in any scientific pursuit. He had a general fondness for science, and was especially interested in astronomy, and in conjunction with his intimate and valued friend, Sir James South, he in early life devoted a good deal of time to astronomical study in the latter's observatory at Kensington.

An unfortunate exposure to east wind brought on an attack of inflammation of the lungs, to which Lord Shaftesbury eventually succumbed on October 1, 1885.

He was elected a Fellow of this Society on November 14, 1828.

Joseph Sidebotham, whose death took place at his residence, Erlesdene, Bowdon, on May 24, 1885, was descended from an old Cheshire county family. He was the younger of the two sons of Joseph Sidebotham, Esq., of Apethorne House, near Hyde, where he was born on January 17, 1824, we believe, only a few months before the death of his father; and was the grandson of John Sidebotham, Esq., of Hoviley. He was for some time a pupil of the famous Rev. Parr Gresswell, of Denton, with whom he continued a close friendship until Mr. Gresswell died at an advanced age. He subsequently went to Manchester business, and served a term with Nelson, Knowles & Co., whose printworks were at Tottington Mill, Bury, and in April, 1849, he joined as a junior partner of six members the firm of the Strines Printing Company, and continued in the company for twenty-eight years, and had been senior partner for many years when he retired in 1876. He remained in business long enough to see his firm the pioneer, on a large scale, in the use of alizarine, to the total discontinuance of the use of madder and its products, and the company early became celebrated for their beautiful scarlets, which for several years yielded large profits.

His cousins, John Sidebotham, Esq., of Kingston House, Hyde, and Edward Lowe Sidebotham, Esq., of Cheltenham and Shepley, left him large properties, including the Hyde and Haughton Collieries, and soon after their death he retired into private life in 1877.

Though well known and highly esteemed as a commercial man and as the head of the oldest calico printing firm in Manchester, he was probably even more esteemed as a man of considerable scientific attainments. He was for more than thirty years an active member of the Manchester Literary and Philosophical Society, and for a long period was a member of the council. Especially was he clever in the microscopical, astronomical, and photographic sections. With the late Bishop Prince Lee he may be said to have been the leader of the photographic section, and subsequently, with Lund, Brothers, Mudd, and others, he founded the Photographic Society, as with Grindon and a few other enthusiasts he founded the Field Naturalists' Society, and was its first treasurer. He was also an enthusiastic botanist. Grindon, in his "Walks and Wild Flowers," says of him, "The upper portion of the Tame Valley between Reddish and Hyde was successfully explored in 1840–42 by Joseph Sidebotham, of Apethorne, a townsman whom we have not more reason to be proud of as a naturalist of the most varied and accurate information, and as one of the most scientific and successful prosecutors of microscopical research, than as a singularly skilful artist in photography. It was Mr. Sidebotham who first drew the attention of Manchester naturalists to the freshwater algae of our district, and who principally determined their form and number. He also it was who collected the principal portion known up to 1858 of the local Diatomaceæ. During the five or six years he devoted to the botany of Bredbury, Reddish, and the banks of the Tame generally, he added no fewer than twenty-five species to the Manchester flora."

He was also an enthusiastic entomologist, and materially increased the list of species of coleoptera and lepidoptera found in his neighbourhood of Hyde, Strines, and Manchester; and he was no less proficient in the science of astronomy.

He was the very intimate friend of James Nasmyth, the famous inventor and no less eminent astronomer. It was to Joseph Sidebotham he first communicated his views of the "willow leaves" structure of the Sun, and many other papers which were first read to the Manchester Literary and Philosophical Society by Mr. Sidebotham.

Mr. Sidebotham was also a personal friend and frequent correspondent of Prof. Piazzi Smyth, the Astronomer-Royal for Scotland, and read some of his first communications on his researches at the Great Pyramid, illustrated by his own photographic views, before the members of the above Manchester Society.

He was too modest a man to care for titles or distinctions, and though he was a Fellow of the Royal Astronomical Society,

the Society of Antiquaries, and many other learned societies, he never used the titles.

He was also a county magistrate of Cheshire, a position he accepted only at the personal urgent request of Lord Egerton, the lord-lieutenant.

He founded, at a cost of some 20,000*l*., including the endowment and rectory, the beautiful church of St. Anne, Haughton.

He always took special interest in the poor boys and youths among his neighbours and workpeople, and gave up much of his leisure to their personal instruction by lectures and otherwise, and many have him to thank for such timely aid for their now comparatively easy and respectable positions in life.

He took great interest in the "Strines Journal," a manuscript work of science and art, conducted by his *employés*, and he frequently contributed articles and drawings to its pages; it now forms a ten years' history of Strines and the neighbourhood and their natural history, which could not easily be surpassed.

He was also a great lover of sacred music, a devoted admirer of Handel and Mozart, and was no mean performer on the organ, as his father was before him. For many years after the opening of Bredbury Church he was the honorary organist there, and did duty every Sunday at that church, the land for which and the large graveyard surrounding it was given by his cousin, John Sidebotham, who also contributed largely to its cost. Joseph Sidebotham made and erected with his own hands the sundial over the south door of that church.

He maried, in 1852, Anne, the only daughter of Mr. Coward, of Manchester, formerly of the firm of Melland & Coward; she died nearly three years ago. He leaves three sons and three daughters to mourn his loss. His remains were deposited by the side of his wife in the parish churchyard of Bowdon.

He was elected a Fellow of this Society on November 11, 1870.

Thomas A. Southwood, M.A., who died at Cheltenham on September 19 last, was born and educated at Devonport. His first step in life was an appointment in the Ordnance Survey in Ireland. He then proceeded to Cambridge, where he graduated in 1843 at the comparatively mature age of thirty-two; and in the same year, after having received and declined the offer of an important post in the St. Petersburg Observatory, he was elected to the Head Mastership of the Modern Department of Cheltenham College. This, the first departure from the old classical school methods, could not have been placed in better hands. Besides being a sound and practised mathematician, familiar with the methods and instruments of science, Mr. Southwood possessed a singular faculty for imparting knowledge; and the new military school, under his management, supplied Addiscombe and Woolwich from year to year with their most promising cadets.

After a brilliant and uniformly successful career of

thirty-six years, Mr. Southwood retired in 1879. He leaves behind him at his death a name and an example which will never be forgotten at Cheltenham College, where his surviving friends and pupils propose to erect a new library to his memory.

He was elected a Fellow of this Society on February 13, 1852.

John Watson was born in the village of Ireshopeburn, near St. John's Chapel, Weardale, on February 10, 1827. He was educated at the village school and at St. John's Chapel. From boyhood he showed a great taste for physical science, and was at all times most industriously given to habits of self-culture.

While still a youth he obtained a humble position in the chemical works of Mr. Hugh Lee Pattinson at Washington, and gradually rose through several minor posts to that of cashier in the office, and later on he became general manager of the works. In 1864 he left Washington to become the founder and managing partner of the chemical works of Messrs. Watson, Kipling & Co., at Seaham Harbour, on the coast of Durham. Though a most industrious worker at his profession, Mr. Watson found time to devote to astronomy, and he showed great genius in the construction, by his own hand and lathe, of telescopes and various optical instruments.

In March 1856 a paper, "On the Outer Ring of Saturn," written by Mr. Watson, was communicated by the Astronomer Royal to the Royal Astronomical Society, and this was followed in January 1857 by a note, "On the Occultation of Jupiter on January 2, 1857." In 1864 he communicated a note, "On a new Binocular Telescope," and since then he has contributed to the *Notices* from time to time, the last communication being "On the Satellites of Mars," in January 1882.

Mr. Watson was well known in the county of Durham as a popular lecturer on astronomy, one of his best known lectures being on the harmony of the Mosaic record of creation with the modern scientific revelations of astronomy and geology. Though not an orator, he had a happy way of imparting knowledge of dry scientific matter in everyday language.

He was familiar with the discoveries of modern science, being well read in the subjects of chemistry and geology, as well as astronomy, and he made meteorological observations for many years at Washington, which formed the subject of some papers on rainfall, &c., in the "Tyneside Naturalists' Transactions." His observatory at Vane House, Seaham Harbour, contains an 8-inch achromatic, with object glass, by Wray. He also worked with a 12-inch, by Messrs. Cooke, of York, and with reflecting telescopes of his own construction, the specula being ground and polished by himself.

Mr. Watson had been in his usual health up to October 30, on the evening of which he was seized with sickness, and, though the best medical aid was procured, the disease, intus-

susception, proved fatal. He died on the afternoon of November 3, at the comparatively early age of fifty-eight, leaving a widow, two sons, and two daughters to mourn his loss.

Trained from childhood in the tenets of the Wesleyan faith, Mr. Watson was, up to the time of his decease, an active member, and loyal supporter of the United Methodist Free Church; but he was ever a man of broad and liberal views, and in his wealthier days gave much, in a quiet way, to various charitable objects.

As an employer of labour he was much respected by all his men, and as a member of various local boards of health and of education he was at all times courteous and useful.

He was elected a Fellow of this Society on November 13, 1857.

Thomas William Webb was born on the 14th day of December, 1807. He was the only son of a clergyman, the Rev. John Webb, rector of Tretire cum Michaelchurch, in the county of Hereford, a living in the gift of Guy's Hospital, which he held with the Vicarage of St. John's, Cardiff. The Rev. John Webb was a good classical and antiquarian scholar; the late Sir Henry Ellis described him as an eminent authority on Norman French, and he was frequently called upon to give evidence in Courts of Law with respect to the interpretation of early documents, but the father of the future astronomer was more particularly devoted to researches respecting the history of the West of England during the period of the Civil War. He had inherited a large collection of MS. matter referring to the Cromwellian period from Baron Pengelly, a connection of the Cromwells, in whose house Richard Cromwell, sometime Lord Protector of England, died. During the greater part of a long life the Rev. John Webb was occupied in preparing a "History of Herefordshire during the Civil War"—a work which, though he lived to the age of ninety-three, he never finished, but his son, Thomas William Webb, with filial devotion, completed and published it after his death. In the preface the son speaks of the long years of thoughtful study which his father had given to the work, and of the dread of inaccuracy or precipitation which prevented its earlier publication. This careful and conscientious spirit was fully inherited by the son, and is a decided feature of his astronomical writings. Although the father did not finish his great work on the "History of Herefordshire," he completed several memoirs for the Society of Antiquaries, and edited more than one volume for the Camden Society, though one of these, "The Military Memoirs of Colonel John Birch," a Cromwellian leader, was left only partly finished, and was completed by his son.

Thomas William Webb's mother died when he was still a child, and his father devoted himself to the boy's education. He was a painstaking, carefully precise boy, preternaturally old and studious, as might have been expected from the child com-

panion of such a father, surrounded by books and MSS. The boy showed some taste for experimenting, and delighted in books on electricity and physics—Natural Philosophy books, as they were called in those days—enjoying them more than a fairy tale. He did "not consider Euclid to be work," and would no doubt have taken to mathematics, but his father did not encourage such proclivities, desiring to make his son a scholar; a term which was identified in his mind with Latin and Greek verse-making and certain refinements of Latin composition, at which the boy worked hard but did not make the progress that his father had hoped. In 1826 he was entered at Oxford and became a Fellow Commoner at Magdalen Hall. In 1829 he took his degree, taking a second class in Mathematical honours. In after years he would excuse himself to younger friends for his University life, saying that he had been very idle, spending most of his time in desultory reading in the libraries. But he was no doubt preparing himself in a satisfactory manner for his future life, perhaps in a much more satisfactory manner than if he had strictly adhered to the University course. From his own account he does not seem to have had bad health, though he was not strong. In after years his strength was decidedly above the average, and he would tramp over the hills of his mountain parish as few clergymen of seventy can.

After leaving Oxford he was ordained a Curate on the 1st of August, 1829, in Hereford Cathedral, and was licensed to the curacy of Pencoyd, where he worked two years, and was not ordained to Priest's orders till the 7th of August, 1831, when he became Minor Canon and Precentor of Gloucester Cathedral. After some ten years' work in Gloucester he returned to Tretire and worked as curate to his father for nearly twenty years. In 1843 he married Henrietta Montague, daughter of Mr. Arthur Wyatt, of Troy House, Monmouth. The marriage took place on the 16th of May at Michel Troy church. In 1852 he was given the living of Hardwick, a large though thinly populated parish near to the Welsh border and Black Mountain district.

Here he wrote "Celestial Objects for Common Telescopes," a book which has made the name of the parish familiar to astronomers all over the world. It may probably be said, without exaggeration, that this book has done more to introduce the possessors of telescopes to the remarkable objects in the heavens, and to create observers, than any other book which has been written. It has no doubt exercised an important and very valuable influence on the method of describing observations. Mr. Webb was greatly attached to the Rev. W. R. Dawes, and would recommend others to take Mr. Dawes's method of describing his observations as their model. Both men were particularly careful and conscientious in their statements, judiciously choosing their language so as to avoid any slight exaggerations as to the accuracy of their estimates or any undue generalisations from isolated facts. Both men were careful to give credit to others, and frequently

summed up very concisely and happily the results of prior observations. In reading any astronomical description by either Mr. Dawes or Mr. Webb, the reader is impressed by the unpretending precision of their style, while he is made fully to appreciate the doubtfulness of the phenomena of which they themselves felt doubtful.

In addition to the "Celestial Objects," which went through four editions, being greatly improved and enlarged by diligent revision at each edition, Mr. Webb wrote largely for periodicals on astronomical subjects. His articles will be found in "Fraser's," "The People's Magazine," "The Intellectual Observer," "The Student," "The Popular Science Review," "The Argonaut," "The English Mechanic," "Nature," and "Knowledge."

His private correspondence with amateur astronomers was very large. He patiently and generously gave his time to advising them with regard to their instruments and the course of work they should undertake. Few things pleased him more than to help in stirring up the enthusiasm of an observer in some distant colony. There must be a large amount of his correspondence treasured up in all parts of the world. His letters were always written in a neat, small hand, which enabled him to put a great deal into the page; and they were frequently illustrated with charming little drawings and enlivened by the quaintest humour, which of its kind is as curious as De Morgan's. His modesty was striking and most unaffected. This seems to have impressed all his friends, as well as his courtesy and obliging kindness as a correspondent, which made him very widely valued and beloved.

Like his friend Mr. Dawes, Mr. Webb was a good draughtsman. His drawings illustrating his observations were made on a smaller scale than is commonly adopted by telescopic observers, as he thought that in making large-scale drawings the observer has a tendency either to fill in more detail than he has actually observed, or to give an appearance of clear definition to details which have been only traced with difficulty. In representing lunar objects, where the multiplicity of clearly traceable detail overpowers the observer, Mr. Webb usually confined himself to diagrams or mere outline maps. In drawing comets, however, where the difficulty lies in faithfully representing delicate differences of brightness, he adopted rather a larger scale than other observers. The plates of the great comet of 1861, given in vol. xxii. of the *Monthly Notices*, do not do justice to his original drawings. His observations of this comet were very striking.

On the evening of June 30, 1861, while standing with his wife in the garden of the Parsonage at Hardwick, he noticed some faint streamers diverging from the nucleus of the great comet then visible. At first he took them for faint narrow lines of cirrus cloud; but their direction pointing to the nucleus of the comet attracted his notice, and on giving closer attention to them he

found that they were slowly closing up like a fan, always pointing to the nucleus of the comet. The observation is described in vol. xxii. of the *Monthly Notices*, and seems to have been an actual observation of the Earth's passage through the tail of the comet. There were two other observers who were fortunate enough to notice the same phenomenon—one, Mr. Williams of Liverpool, and the other in the Antipodes.

In a volume entitled "The Industrial Progress of New South Wales," published by authority of the Colonial Government, is a paper by Mr. Tebbutt, in which he says that while observing in Australia, on the morning of July 1, 1861 (*i.e.* really in the afternoon before sunset of our June 30) he noticed the widening out of the branches of the tail of the comet then visible. He remarks that this observation is very interesting when taken in connection with the announcement made by Mr. Hind that it appeared probable that in the course of June 30, 1861, the Earth passed through the tail of the comet at a distance of perhaps two-thirds of its length from the nucleus.

Mr. Webb and Mr. Williams observed the closing up of the streamers of the tail while Mr. Tebbutt in Australia observed the opening out of the streamers a few hours before, as the Earth entered the tail.

On Sept. 7, 1884, Mrs. Webb died from apoplexy. Her husband was completely prostrated by the sudden blow, and his health gradually failed, till he died, eight months after, on May 19, 1885, at Hardwick, the parish to which he had been devoted for nearly thirty years. If he had lived to December, he would have completed his seventy-eighth year.

In 1882 he was appointed one of the Prebendaries of Hereford Cathedral, an office which only required a month's attendance during the year, and would have separated him but little from his beloved parish.

He was elected a Fellow of this Society 1852, Jan. 9.

A. C. R.

William Wray was born at Whitby, in Yorkshire, on December 6, 1829.

His father, who was a sea-captain, wished to take him to sea, but his mother objecting, he was articled to a solicitor. He had a great love for astronomy and optics, and amused himself by constructing some reflecting telescopes, but not being satisfied with these, he turned his attention to the refractor, and made numerous experiments with a view to dispensing with flint glass, which was expensive, and at that time difficult to procure of good quality. These experiments were not practically successful.

Not liking the legal profession, he came to London in the year 1850, and commenced the practice of an optician, devoting himself at first chiefly to the construction of microscope objectives, and was perhaps the first professional optician who used

the single front lens for the higher powers, in place of the older triple combination.

He spent much time in experiments for the reduction of the secondary spectrum, and succeeded in making object glasses practically free from outstanding colour; but these were unfortunately not permanent, owing to the fact that only fluids had the required dispersion, and in consequence of their contraction and expansion it was found to be quite impossible to retain them between the lenses for any great length of time.

He was very successful in the construction of both telescope and microscope objectives, and made a great improvement in the former by the substitution of light in place of the dense flint glass as usually used, thus lessening the secondary spectrum in a marked degree.

Owing to ill health he had been unable to take an active part in the business for some years.

He was elected a Fellow of this Society on January 10, 1862.

Colonel William Yolland, C.B., F.R.S., was born on March 17, 1810, at Merrifield, Plympton St. Mary's, Devon. In early life he was admitted into the Royal Academy at Woolwich, where he obtained his commission in the Royal Engineers in 1828.

He rose by regular promotion until he became lieutenant-colonel in 1855, and a brevet colonel in the army in 1858. Colonel Yolland early developed a faculty for mathematical and geodesical studies, which he cultivated with signal success. His abilities found scope in Canada shortly after his admission to the Royal Engineers, and he was subsequently employed at the Ordnance Survey at the Tower of London, at Southampton, Dublin, and Enniskillen. During this interval he superintended the publication of astronomical observations made with Ramsden's zenith sector, and afterwards with Airy's, the latter being for the purpose of determining the latitudes of various trigonometrical stations in Great Britain and Ireland. He also compiled an account of the measurement of the Loch Foyle base, which was made during the years 1827–29. The article on Geodesy which forms part of the mathematical text-book used at the Royal Military College was written by Colonel Yolland at the express request of Colonel Harness, who was at that time Assistant Inspector-General of Fortifications. In 1854 Colonel Yolland was appointed one of the Inspectors of Railways under the Board of Trade, in which capacity his name has been often before the public.

While in the service of the Board of Trade he was appointed superintending engineer of the Ramsgate Harbour Works, but this appointment he resigned, after holding it only a few months.

In 1856 his wide experience and sound judgment led to his

being selected as the engineer member of the Commission appointed by the Secretary of State for War to consider the best mode of reorganising the system of training officers of the scientific corps, with the special intention of abolishing patronage and opening the commissions in those corps to competition. The Commissioners, the other two of whom were Colonel W. J. Smith, R.A., and the Rev. W. C. Lake, visited France, Prussia, Austria, and Sardinia; and after studying the methods of appointment in use in those countries, drew up a report, which was printed by order of the House of Commons.

On the retirement of Sir Henry Tyler from the office of Chief Inspector of Railways under the Board of Trade, he became the senior inspector, and held this appointment at the date of his death, having thus been thirty-one years in the service of the Board of Trade.

He received the distinction of C.B. (Civil) in 1881. Colonel Yolland died at Baddesley Vicarage, Atherstone, Warwickshire, where he was making a temporary stay with his family, on September 4, 1885.

He was elected a Fellow of this Society on February 14, 1840.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received by the Council from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.

The regular meridian work of this Observatory has proceeded without interruption throughout the year, and has been continued on the same lines as before. 5,374 transits and 4,664 meridian zenith distances were observed in the year 1885, the total number of stars observed being 1,415. A considerable number of transits were observed by eye and ear, the chronograph having been out of use during January, February, and part of March, whilst various repairs necessitated by its long and constant use, and some improvements suggested by experience, were carried out by Messrs. E. Dent & Co. As the observers have, under ordinary circumstances, little practice in eye-and-ear transits, it has been made a rule to observe two clock-stars by this method on each night of observation with the transit circle. The observations with the "reversion prism" have been continued as in 1884, and the existence of a small personal error depending on the direction of motion would appear to be fairly well established, though the quantity is so small that many more observations will be required for its accurate measurement. The altazimuth has also been used as follows to investigate this "personality:"—two transits of the same object are observed in close succession, and the eyepiece is rotated through 90° (reversing the direction of apparent motion) at the middle wire of the first transit, and back to its original position at the middle wire of the second, giving virtually a pair of symmetrical transits of the object with apparent motion in opposite directions; or, with a rotation of 45° instead of 90°, a comparison of horizontal and vertical transits may be obtained. The results are satisfactorily in accordance with those given by the transit-circle.

A special instrument has been devised for the further investigation of the whole subject of "Personal Equation," by means of which transits of limbs of an artificial sun and moon or

artificial stars can be observed with the transit-circle, and the actual times of transit recorded automatically on the chronograph. The artificial objects are apertures in a vertical plate, which is placed in the focus of an object-glass of about 7 inches aperture and 50 feet focal length (attached to the dew cap of the transit-circle when horizontal and pointing north), and is carried smoothly by clockwork from east to west or west to east, at a rate which may be varied at will from that of a close circumpolar star to three or four times that of an equatorial star. The apertures in the plate are illuminated by a mirror placed behind, which reflects the Sun's or Moon's rays to the object glass. The automatic registration is effected by the contact of insulated platinum studs affixed to the plate and corresponding to the artificial objects, with other fixed studs corresponding to the wires of the transit-circle. The instrument is now complete, and a few observations have been made with it.

The mean error in R.A. of Hansen's Lunar Tables with Professor Newcomb's corrections is $+0^{s}\cdot028$ for the year 1885, as deduced from 105 observations with the transit-circle.

Three determinations of flexure of the transit-circle in 1885 gave results $+0''\cdot08$, $-0''\cdot08$, and $0''\cdot00$ respectively; the mean of five determinations in 1884 was $+0''\cdot18$, and of five in 1883, $-0''\cdot49$. Since 1879 no separate correction for flexure has been applied.

The apparent correction to the nadir observation deduced from reflexion observations of stars in 1885 is $-0''\cdot27$, as compared with $-0''\cdot45$ in 1883, and $-0''\cdot36$ in 1884.

The equality of successive intervals of the micrometer screws of the six transit-circle microscopes was investigated in March, and it was found that though there was evidence of considerable wear in the individual screws, the effect was eliminated from the mean (within $0''\cdot05$) by the method of using them, the action of the spring being in opposite directions for the micrometers of each pair. It has been decided, however, to replace them by new steel screws, which were constructed by Mr. Simms, and brought into use on January 1, 1886, the four supplementary microscopes being used in the preceding month, whilst the new screws were being applied to the six ordinary micrometers.

The altazimuth observations of the Moon in the first and last quarters have been continued through 1885. The reversion-prism eyepiece has been used to reverse the apparent direction of motion in one position of the instrument for each double observation of azimuth or zenith distance, so as to eliminate personality depending on the direction of motion.

With the reflex zenith tube 41 transits of γ *Draconis*, at temperatures ranging from 45° to 71°, and 6 transits of 9 *Aurigæ*, at temperatures ranging from 41° to 56°, have been observed; these observations, and those made in 1883 and 1884, seem to show that the temperature correction to an interval of the wires is not well enough marked to explain the anomalous parallax of

γ *Draconis* deduced from observations made with this instrument.

The Lassell Equatorial is now in working order, and has been used during the past year for observing occultations and phenomena. Various small additions and improvements have been required; a lamp has been fitted for illuminating the field, a new plane mirror (silver on glass) has been supplied by Mr. Calver, and the apparatus for slow motion in R.A. has been modified, so that it can be used without disconnecting the clock. The definition obtained with this instrument is occasionally extremely good, but air currents, occasioned by the heat of the observer's body, sometimes give trouble.

On the recommendation of the Board of Visitors, the Treasury have sanctioned an important addition to the optical means of this Observatory in the shape of a refractor of 28 inches aperture and 28 feet focal length, to be mounted on the south-east equatorial, in place of the present telescope of $12\frac{3}{4}$ inches aperture. With this instrument the number of stars available for observation with the spectroscope should be largely increased. The work of constructing and mounting the object-glass has been entrusted to Mr. Howard Grubb.

Comet *a* 1885 has been observed on one night; Comet *c* 1885 on three nights; Comet *d* 1885 on three nights; and Comet *e* 1885 on one night with the equatorials. Twenty-seven occultations of stars by the Moon as well as the occultation of *Uranus* on November 30 have been observed, in most cases by two or three observers, and sixty-three phenomena of *Jupiter's* satellites. The plurality of observers has thrown some light on the probable error of these observations, which does not seem to be appreciably greater for occultations or transits of satellites than for eclipses.

The following spectroscopic observations have been made with the half-prism spectroscope mounted on the S.E. equatorial:—234 measures of the displacement of the F line in the spectra of 43 stars; 53 of the *b* lines in the spectra of 11 stars; together with 70 comparisons of the hydrogen or magnesium lines with the corresponding lines in the spectrum of the Moon or of the Sun, 15 measures of the displacement of the *b* lines in the spectrum of *Venus*, 18 measures of the relative displacement of the *b* lines at the E. and W. limbs of *Jupiter*, and 6 at the N. and S. limbs, also 10 of the relative displacement of the same lines at the preceding and following ansæ of *Saturn's* ring, as a check on the general accuracy of the results for star motions The spectrum of the new star in the great nebula in *Andromeda* was observed with one or other of the spectroscopes of the Royal Observatory on five nights, that of Mr. Gore's *Nova Orionis* on one night. The chromosphere was completely observed on six occasions, and the spectrum of the large sun-spot, which developed so remarkably from July 5 to July 11, on one occasion.

In the year 1885, 428 photographs of the Sun were taken at Greenwich on 206 days. The Greenwich photographs have been

supplemented by photographs, taken on 79 days, received from Dehra Dûn for the period January to October 16, 1885.

The spectroscopic observations are completely reduced to the end of 1885 and are ready for press. The photographs of the Sun are completely measured and reduced to the end of 1885.

A large number of measures of areas and positions of spots have been made during the year 1885 for determination of the probable error of a single measure, and there is every reason to be satisfied with the results obtained.

The magnetical and meteorological observations are continued generally on the same plan as in former years. Absolute determinations of magnetic declinations are made daily, of horizontal force monthly, and of dip frequently during each month. And by means of photography a continuous record is kept of the variations of declination, horizontal force, and vertical force, as well as of the earth currents which appear in two independent lines of wire. The magnetic results are printed in such shape as to give as much information as possible in regard to magnetic movements, and in all cases of unusual motion of any significance reproductions of the original curves are given, those of the different elements being placed one under the other, so that they may be readily compared. The complete registration of magnetic and solar phenomena in one establishment gives, it is believed, special advantages as respects the comparison of these related phenomena.

With a view of obtaining greater uniformity of temperature in the magnet basement, a line of pipes has been laid underground, for its ventilation by air which has acquired the temperature of the soil at a depth of 10 feet.

The meteorological registers comprise photographic record of the variations of the barometer, of the dry and wet bulb thermometers, and of atmospheric electricity, with continuous automatic record of the deviation, pressure, and velocity of the wind, and of the amount of sunshine and rainfall. Observations are also made daily of the temperature of the soil at depths of 3, 6, 12, and 24 feet respectively below the surface. Results deduced from the meteorological observations and records are printed in the annual volume so far as seems desirable.

At the beginning of the year 1886 the new photographic thermometer apparatus for registration of the temperatures of the air and of evaporation was brought into regular use. It is proposed for a time to continue the records both with the old and new apparatus for the purpose of making comparison between them. Observations of the temperature of the air in an exposed situation on the roof of the Magnet House were also commenced at the same time.

Watch is kept for a few of the principal meteor showers, though great attention cannot be paid to work of this kind. Observations were made, as far as possible, of the meteors in connection with Biela's Comet on November 27, 1885, but the weather at Greenwich was extremely unfavourable.

The volume of Greenwich Observations for 1883 was distributed in September last, and the printing of that for 1884 is well advanced, though there has been some pressure of work in this connection owing to the long-continued maximum of Sun-spots, and the undertaking of several minor investigations bearing on the results.

The heated-chamber for testing Government chronometers has been supplied with a contrivance, invented by Mr. Kullberg, for automatically regulating the temperature; by means of this instrument it has been found possible to maintain the temperature constant within narrow limits. A double casing to the chamber, packed with a non-conducting material (slag-wool), materially contributes to constancy of temperature.

In the summer of 1885 Commander Moore and Lieutenant Douglas, of the Royal Navy, made a series of observations at this Observatory for a comparison of the respective merits of sextants and small transit instruments for determining local time. In connection with this work a telegraphic determination of the difference of longitude between Greenwich and Gibraltar has been made under the superintendence of the Hydrographer, the local time being determined at each station by means of the sextant. Sets of signals were exchanged between Greenwich and Gibraltar on three days, the signals at Greenwich being observed by four or five observers.

Armagh Observatory.

The building for the new equatorial was erected in July last, about 100 feet south of the Observatory. It is similar to that supplied by Mr. Grubb for the Natal Observatory, but is of rather more substantial construction, with a carefully planed cast-iron wall-plate, on which the dome moves on six "canted" wheels. The dome is covered with papier-mâché, rivetted to the iron framework and stitched together with copper wire. A small porch affords room for the clock, battery, shelves, table, &c. Under this "Robinson Memorial Dome" was next erected an equatorial refractor by Mr. Grubb, having an excellent object-glass of 10 inches aperture and 10 feet focal length. The declination circle can be read from the eye end, and both it and the R.A. circle can be illuminated by small incandescent lamps worked by a two-cell bichromate battery. There is a third lamp over the table in the porch to throw light on maps or working lists.

The carpenters' and painters' work was not finished till the end of September, when the instrument was at once adjusted and brought into use. A series of micrometric observations of nebulæ has been commenced with a small micrometer, having steel bars instead of wires, and requiring no illumination. This micrometer has only one screw, but it is attached to a slipping-

piece, which moves it bodily in the direction of the position wire. More delicate measures will be made with a bifilar micrometer with electric illumination, which forms Mr. Grubb's contribution to the Robinson Memorial, and which will shortly be ready for use.

The printing of the "Second Armagh Catalogue of 3,300 stars" has progressed very slowly, and is not yet finished. It is, however, hoped that it will be distributed in the spring. It has revealed some interesting cases of proper motion, of which an account will soon be laid before the Society.

Cambridge Observatory.

The observations during the year have been almost exclusively made with the meridian circle, for the purpose of determining instrumental errors, and of supplying the places of stars which had either been passed over in the regular zone work of previous years, or had not been observed the prescribed number of times.

2,635 meridian observations have thus been taken in 1885, all read off with four microscopes, and all, with very few exceptions, taken at five or seven wires. 1,936 of these observations are of stars within the zone; 583 of standard clock stars; 60 are observations of *Polaris* above the pole, involving 134 circle readings; and 56 of *Polaris* below the pole, involving 118 circle readings.

The number of nights suitable for observing zone stars was 92, which is rather below the average.

Collimation, level, and nadir point were taken 189 times.

The entire number of observations of zone stars now amounts to 43,450. The apparent Right Ascension and North Polar distances are deduced from these up to June 5, 1885.

The mean R.A. and N.P.D. for January 1 are obtained up to 1880, February 17. The reductions to epoch are progressing as fast as time and the pressure of the work will allow.

The level and collimation are computed to the end of 1885.

The mean level error for the year is $-3''{\cdot}54$, a very slight increase negatively on that of the previous year — so slight, indeed, that the apparent change may be due to errors of observation.

A large number of observations have been made for the purpose of ascertaining the errors of division of the west circle. An apparent discrepancy between the zenith and nadir points is now undergoing investigation.

A fresh determination of the coefficient of flexure was made by means of observations extending from May 29 to July 17.

The final result from 200 observations of the north and south

collimators gives for the arc from north horizon, through zenith, to south horizon

$$180° 0' 1''{\cdot}00 \pm ''{\cdot}018$$

instead of 180°.

The correction of the circle reading for flexure, therefore, supposing it to vary as the sine of the zenith distance, will be

$$-0''{\cdot}50 \sin z,$$

when z is the zenith distance, + when S, − when N; which is sensibly less than the former result.

Dunsink Observatory.

During the past year the South Equatorial has been employed as usual in observations on Stellar Parallax. A series of measures from *Nova Andromedæ* to two other stars in the vicinity have also been carried on as long as the *Nova* remained visible.

The meridian circle and chronograph have been employed during the year in observing the list of southern stars mentioned in former reports. The majority of those still unobserved at the beginning of the year come on the meridian at night during the summer months, and as the assistant, Mr. Rambaut, was unable, from the effects of an accident, to observe for a considerable time during May and June, many of them have been again omitted.

Towards the end of the summer a new working list was compiled, consisting of stars with proper motions greater than $0''{\cdot}2$ annually. These were taken chiefly from Struve's "Positiones Mediæ," Argelander's list of 250 stars in Vol. VII. of the "Bonn Observations," and the list of stars given by Dr. Robinson in the Introduction to the Armagh Catalogue for 1840, along with some others taken from the Catalogues of Mr. Main and Mr. Stone in the "Memoirs of the Royal Astronomical Society." This list, with the former one, has been in use since September.

During the year the right ascensions of 730 stars and the declinations of 413 have been observed.

For the determinations of the clock error and the azimuth error of the instrument the fundamental stars of the "Berliner Jahrbuch" are used. Of these 273 transits of time stars and 67 of polar stars have been observed. The error of collimation of the instrument has been determined 168 times, the level error 112 times, and the error of runs of the microscopes 86 times. The nadir point has been observed 170 times, but since September the declinations of standard stars from the "Berliner Jahrbuch" have been observed in addition as a check on the accuracy of the nadir readings, two or more being observed each night for this

purpose. The mean of the determinations of the nadir point by both methods is that used in the reductions. Early in January, owing to a web which had grown over them, it became necessary to clean the spider lines in the meridian circle. This was done on January 5th, and the same corrections to the middle wire as before were used in the reductions. In August it was recognised that the wires had been disturbed by the process of cleaning, and that it was necessary to determine their distance over again. For this purpose 23 transits of polar stars were taken on 19 nights between August 11th and December 10th, but the majority of these, having been broken by clouds and being otherwise defective, the final intervals were made to depend on seven complete transits of *Polaris*. The wire distances were found so changed from what they had been before, that it was necessary to go back over all the reductions which had been done up to that time, and a complete set of new tables for reducing lateral wires to the middle had to be computed.

Royal Observatory, Edinburgh.

During the year 1885 the daily time-signals by ball and gun, as well as the control of certain mean-time clocks in the city, by original star observations in and electric currents from the Royal Observatory, Edinburgh, have been kept up as usual. Also the computing of the meteorological observations at fifty-five of the stations in Scotland of the Scottish Meteorological Society, and then furnishing the resulting numbers with remarks upon them to the Registrar-General of Births, Deaths, &c., in Scotland, for that officer's monthly and quarterly reports, where they have been duly printed.

A still more directly important work during the last eleven months has been the resumption of the printing of the "Edinburgh Star Catalogue and Ephemeris for 1830 to 1890." This step was rendered possible by an arrangement made last February with the Lords Commissioners of H.M. Treasury by the Right Honourable Sir William Vernon Harcourt, then Home Secretary, and by consequence Governmental Chief of the Observatory.

The printing began immediately thereafter, has continued without cessation up to the present time, has reached from 4^h to 17^h Right Ascension; and the astronomer has been much indebted to the unfailing care and rigorous severity with which the two assistant astronomers, Mr. Thomas Heath, B.A., and Mr. H. Ride, have day by day read the proof-sheets and revises against the original manuscript calculations, as well as the fair copy prepared for the printer to work by.

In the month of June the astronomer communicated to the Royal Society, Edinburgh, three successively and independently observed solar spectra, each extending through 60 double quarto

plates. The Society has had them photo-lithographed on a rather reduced scale, and they are expected to appear in the forthcoming volume of *Transactions* (xxxii.), before the end of the present month.

Glasgow Observatory.

The astronomical work at the Glasgow Observatory during the past year has been considerably impeded by the exertions necessarily made for the purpose of placing upon a satisfactory footing the meteorological operations of the establishment. From the beginning of 1868 a system of meteorological observations by the use of self-recording instruments had been conducted at the Observatory at the expense of the Meteorological Office in London. Early in 1883, however, the authorities of the Meteorological Office announced to the Glasgow Observatory, and also to several of the other observatories affiliated to the Office, their intention of withdrawing their support from the establishments at the close of the year, but they liberally offered to place a complete set of instruments at the disposal of any observatory provided an adequate fund was raised by local efforts for the continued prosecution of the observations. The final result, in so far as the Glasgow Observatory is concerned, has been satisfactory. By the co-operation of the Town Council and the Clyde Trustees with the authorities of the University of Glasgow, the maintenance of the meteorological operations has been secured. The connection with the Meteorological Office has also been re-established to a considerable extent as in former years. The astronomical operations during the past year have been necessarily confined to observations of a select list of stars with the transit circle.

Kew Observatory of the Royal Society, Richmond.

The sketches of sun-spots, as seen projected on the photo-heliograph screen, have been made on 176 days, in order to continue Schwabe's enumeration.

422 observations of solar and sidereal transits have been taken for the purpose of keeping correct local time at the Observatory.

In consequence of the increasing number of sextants sent to the Observatory for examination, it was found desirable to provide special accommodation within the building for the work. As the room known as the Pendulum-room was unoccupied, it was resolved to convert the apartment into a Sextant-room, and accordingly the Cooke testing apparatus was dismounted from the South Hall and erected in it. Four careful redeterminations

were then made of the angles between the collimators, and they were found to have been unaffected by transfer of the apparatus to the new position.

The arrangements for rating of watches have been continued during the year with great success, and up to the present 397 watches have been tried, of which 41 were submitted by the owners and 356 by the manufacturers or dealers.

The watches received during the year were entered for testing in the following classes:—For class A, 339; class B, 44; and class C, 14. Of these, 98 failed to gain any certificate; 13 passed in C, 111 in B, 169 in A, and 6 obtained the highest possible form of certificate, the class A, "ESPECIALLY GOOD."

In July, owing to the numerous requests from manufacturers and others, a system of awarding marks to class A watches, indicating the degree of relative efficiency exhibited during trial, was adopted, being based upon plans already in use in the Geneva and Yale Observatories. In it the number of marks awarded to an absolutely perfect watch is a hundred, made up as follows:—forty for a complete absence of variation of daily rate, forty for absolute freedom from change of rate with change of position, and twenty for perfect compensation for effects of alteration of temperature.

As, however, the trials already in use do not comprise a test for the going of travellers' or explorers' watches, experiments are in progress with a view of constructing apparatus to test the behaviour of watches when subjected to such motion as they experience in the case of daily wear and travelling, in order to make a special examination on this point for watches submitted for trial by the Royal Geographical Society.

A series of tests for pocket chronographs has also been introduced by special request of the Cyclists' Union.

The committee have also in contemplation the rating of marine chronometers for the public, and for that purpose a chronometer oven, constructed after the model of the apparatus at the Royal Observatory, Greenwich, for the Board of Trade some years ago, has been placed at their disposal by that department, and is now erected at the Observatory.

Enquiries have been instituted as to the various methods of rating at the Royal Observatory and at the Observatories at Liverpool (Bidston), Hamburg, Wilhelmshaven, Kiel, Geneva, Washington, and Yale, with the view of enabling the committee to decide upon the most suitable system to be adopted by them.

The usual magnetical and meteorological observations and reductions, and also the verification of instruments, operations to which the attention of the Observatory is mainly directed, have been carried on as formerly.

Liverpool Observatory, Bidston, Birkenhead.

The work has been of the same character as in previous years. Careful attention has been given to transit observations for the determination of clock errors and to the communication of accurate time to the port. The time gun on the Morpeth pier has been fired at 1^h p.m. daily, Sundays excepted. No instance in which the gun has failed to fire has occurred during the past year, and the flash has in each case agreed with the time shown by the normal clock in the chronometer room. The daily comparisons of clocks and chronometers have been made as heretofore. Two hundred and sixty-four chronometers have been tested during the past year, and records of the performance at sea of the chronometers of the Pacific Steam Navigation Company during twenty-six voyages of their ships from Liverpool to Valparaiso and back to Liverpool have been received. Each ship carried three chronometers, and by giving equal weight to each of the three the mean error of longitude for an average voyage of one hundred and one days was under three miles.

No change has been made in the meteorological work. Telegrams have been sent daily to the Meteorological Office and to the Liverpool Underwriters' Association. Weekly results have been sent to the Medical Officers of Health for Liverpool and Birkenhead, and to the Registrar-General, to whom monthly results have also been forwarded.

In May last the late Mr. John Hartnup retired from the post which he had held for nearly forty-two years with so much credit to himself and advantage to the mercantile marine of the Port of Liverpool, and his son, Mr. John Hartnup, jun., for many years Assistant at this Observatory, was appointed Director.

Radcliffe Observatory, Oxford.

The following have been the subjects of observation during the year 1885:—

With the Transit Circle:

1. Observations of stars to the seventh magnitude inclusive between 115° N.P.D. and the Equator.

2. Observations of the Moon, which are continued throughout the lunation, and regularly compared with the Right Ascensions and North Polar distances of Hansen's Lunar Tables. Such comparisons have been generally discontinued, and these results appear, therefore, to have a special value in keeping distinctly before astronomers the extraordinary character of the change between the results of observation and theory which took place about 1864, and has led in the following twenty-two years to

discordances in mean longitude between Hansen's Tables and observation of more than fifteen seconds of arc.

3. Observations of the Sun.

4. Reflexion observations to test the freedom of the instrument from systematic errors.

The following table gives the number of observations made during 1885 :—

Transits, 3,500.
Circle observations, 3,440.

These totals include :

Observations of the Moon on 58 days.
" " " Sun " 90 days.
35 Reflexion observations of stars.
460 Determinations of nadir point.
2 Durations of passage of Moon's diameter.
4 Vertical diameters of the Moon.
4 Observations in R.A. } of *Nova Andromedæ*.
6 " in N.P.D. }

With the extra-meridional instruments :

31 Determinations of the magnitude of *Nova Andromedæ* from Sept. 9 (8th mag.) to Dec. 10 (14th mag.) [see *R.A.S. Notices*, vol. xlvi. No. 2].
25 Observations of 15 occultations of stars by the Moon.
1 Observation occultation disappearance of *Uranus*.
2 Observations " reappearance " "
5 " of 3 eclipses of *Jupiter's* IV. satellite.
Measurement of bright solar halo with parhelia on Dec. 30.

The volume for 1882 has been printed and distributed.

The volume for 1883 is nearly ready for press.

The observations made in 1884 are completely reduced.

The observations made in 1885 are nearly reduced to the end of the year.

Oxford University Observatory.

During the past year the attention of the observers has been absorbed by the completion of the *Uranometria Nova Oxoniensis*, and by passing this work through the press. Independently of much preliminary work, commencing in October 1881, the first published determination of magnitude was made in December 1881, the last was made in October, 1885, and the entire work was published at the end of November of that same year.

The *Nova* in the nebula of *Andromeda* and that in *Orion* have been constantly observed, and a few measures were made of the translucency of discs of optical glass, which remain for communication to the Astronomical Society. The only other work prosecuted at this Observatory consisted in many lectures delivered by the Professor to students in the University, and much time was also devoted by the assistants to the instruction in practical work.

It is proposed now to devote the instruments in the Observatory to photography and spectroscopy. In the first place, two constellations will be selected—*Cassiopeia* and *Lyra*—with the view of giving what may be termed their natural history, in respect of brightness, configuration, and constitution, including, if possible, the motion of the brighter stars in the line of sight. The photographs will be confined to small plates, including an area of about one degree square, with the view of obtaining charts admitting of as accurate measurement as with a micrometer applied directly to the sky. The experiment is somewhat formidable, but will be steadily prosecuted.

Temple Observatory, Rugby.

During the year 1885 the usual attention has been given on fine evenings to members of the school, and the Observatory has been open for such purpose seventy-eight times.

In original research, Mr. Seabroke has been giving up nearly the whole of his available time to the spectroscopic measurements of the motion of stars in the line of sight. A very considerable period has been absorbed in alteration of the optical arrangements, which are not now considered final, and a spectroscope, with bisulphide of carbon prisms, is being constructed for trial.

Besides trial observations, 65 sets of measures, of an average of six each in each set of 33 stars, have been made.

The measurement of double stars has been continued, but, owing to other work, the progress of former years has not been equalled; 163 sets of measures of 94 stars have been made by Mr. Percy Smith.

Stonyhurst College Observatory.

The solar work for the year consists of 233 drawings of the sun, to the scale of 10·5 inches to the diameter, taken on 230 different days, and special attention has been given to the general surface whenever the sky was favourable. The measurement of spot-area is progressing fairly. The entire chromosphere was measured on 79 days, and partially on two others; the results are published in "The Observatory." Sun-spot spectra have been examined by the Rev. A. Cortis, S.J., on ten days in 1885,

and the series of observations in preceding years is being reduced for publication.

Observations have been made of *Jupiter's* satellites, of lunar occultations, and of comets, but the weather has greatly interfered with the watch for meteors on the most important nights of the year. A list of observed meteors has been forwarded to Mr. Denning for comparison with other observations.

The *Nova Andromedæ* was examined on all fine nights, from its first appearance until it was scarcely perceptible in the 8-in. Equatorial.

The latest addition to our astronomical instruments are a Hilger solar prism, to which a Dawes eyepiece is adapted, both presented to the Observatory by I. Roberts, Esq., and a powerful direct-vision stellar spectroscope.

The upper glow continues to be watched carefully. The day-glow is never entirely absent, whilst the after-glow appears to be intermittent, or at least of varying intensity. On two occasions a recurrence of the after-glow took place some forty minutes after the first display had wholly disappeared. A glow around the moon has been not unfrequently observed.

A paper by Dr. B. Stewart has been read before the Royal Society on a comparison of the magnetograms of Kew and Stonyhurst; and copies of the photo-curves and of other magnetic results have been forwarded to Prof. W. G. Adams and to A. Schück for comparison with similar observations. The self-recording meteorological and magnetic instruments have suffered no interruption during the past twelve months.

Mr. Barclay's Observatory, Leyton, Essex.

The series of double-star observations is continued, as well as observations of the phenomena of *Jupiter's* and *Saturn's* satellites. The instruments remain the same as in former years.

The past year has been exceedingly unfavourable for astronomical observations.

Mr. Common's Observatory, Ealing.

Experiments in stellar and astronomical photography with various kinds of telescopes have been made. The De La Rue polishing machine has been removed from the University Observatory, Oxford, and erected in the workshop, and a temporary mounting and house is in the course of erection for further experiments.

A comet was found on the night of Friday, the 4th of September, and change of position noticed that evening. This proved to be a comet already found a few days before by Brooks in America. A series of observations were made on the Nova in *Andromeda* immediately after the announcement from Dun Echt.

The Earl of Crawford's Observatory, Dun Echt.

During the early part of the year 1885 micrometric observations of *Jupiter*, *Saturn*, and a few close double stars were made. In the summer considerable time was devoted to the library, the complete press-marking of which, to the number of over 15,000 volumes and pamphlets, was completed by Mr. Robert Copeland, acting as temporary librarian.

In the month of June Mr. J. G. Lohse left Dun Echt for Mr. Wigglesworth's new Observatory at Scarborough, after eight years of most zealous devotion to his varied astronomical duties at this Observatory. In the same month vol. iii. of the Observatory publications was published.

In July Dr. L. Becker, who succeeded Mr. Lohse, commenced a series of observations in the prime-vertical with a view to determining the latitude of the place as well as the differences of declination of a select list of stars. Dr. Becker has also determined the places of a variety of objects with the transit-circle in combination with direct and reflected observations of the pole star.

In the autumn and close of the year frequent observations, both spectroscopic and micrometric, were made of the "new" stars in *Andromeda* and *Orion*, chiefly by Dr. Copeland. In the first star traces of the F line are believed to have been recognised, while in the second the bright hydro-carbon bands form one of the most conspicuous spectroscopic features as seen in the Dun Echt instruments. It is confidently believed that these bright bands are to be traced with more or less certainty in all spectra of Secchi's third type. The large stellar spectroscope by Messrs. T. Cooke & Sons, mentioned in the last Report, was received in September. Although somewhat incomplete its performance was extremely satisfactory. It is expected that it can be brought into regular use by the middle of March.

In the course of the year fourteen circulars have been distributed, ten of which deal exclusively with comets. For computations of elements and ephemerides special thanks are due to Dr. H. Oppenheim of Berlin. The remaining circulars refer to the new stars and to the prediction of the Biela meteors, which were duly observed at Dun Echt. Electric illumination of apparatus with Swan lamps has been introduced with great advantage.

The daily meteorological observations and the firing of the time-gun at Greenwich noon every Saturday have been continued as in former years.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

The phenomena of the satellites of *Jupiter* and *Saturn* have been observed as in previous years. Some photometric measures have also been made with one of Prof. Pritchard's wedge photometers, made by Mr. Hilger.

The 3-ft. reflector took up much time last winter; it was set up here in the building constructed by Mr. A. A. Common, F.R.S., and tried on every suitable night. During the year several mechanical improvements, chiefly at the eye-end, have been effected. The new observatory for this telescope will, it is expected, be completed very shortly.

The Earl of Rosse's Observatory, Birr Castle, Parsonstown.

During the past year observations have been made on 87 nights. Water pressure of 60-ft. head has been applied to the driving clock of the 6-ft. reflector through the impact of a jet $\frac{1}{4}$ inch diameter, in substitution for a descending weight of 30 cwt., descending six inches per minute, and the tube, by means of an additional counterpoise, has been satisfactorily brought within the power of *one* man for raising and lowering. A speaking tube from the eyepiece to the attendant below has been added. These two alterations have enabled the telescope to be worked by two men with at least as much ease as by three before the change.

Our work has, however, been rather directed to photometry and lunar heat, without the aid of the 6-ft., than to the nebulæ. Our determinations of the heat of the moon during the eclipse of 1884, October 4, were published in the "Transactions of the Royal Dublin Society" during the year 1885. The meteorological observations have been continued as usual.

Lieut.-Colonel Tupman's Observatory, Harrow.

The meridian circle has been employed in determining the latitude and longitude of the Observatory, and in observations of the R.A. of the Moon between sunset and 13^h, 54 transits of the Moon having been obtained. The collimation, level, and azimuth errors have been determined on 80, 110, and 87 days respectively, and prove the mounting to be very stable. The equatorial intervals of the wires, the inequality of the pivots and the values of one revolution of the screws of the eyepiece micrometers have been investigated. The collimators, mounted on iron pillars out of the meridian, as described in Report last year, have been found to be not sufficiently steady. The collimation error has

always been obtained by reversing the instrument either to observe one of the collimators or over mercury. It is nearly always difficult to use the mercury trough, even when hung in rubber slings, owing to the vibrations of the soil.

The co-latitude obtained from nine stars passing near the zenith and the observed nadir points is 38° 25′ 13″·2, while from forty other stars at all zenith distances it is 38° 25′ 12″·7, the difference being probably due to division errors.

The longitude from Greenwich was found by transporting two chronometers to the establishment of Messrs. E. Dent & Co., 61 Strand, and there receiving by eye and ear the automatic signals from the mean solar standard clock of the Royal Observatory at 1^h and 2^h, and immediately taking them back to Harrow. The interval of time during which the chronometers were trusted never much exceeded three hours. This was done on six days with the following results:—

1885.	Longitude. [m. s.]
March 28	1· 19·95 West
April 13	1· 20·07
April 18	1· 19·95
May 11	1· 19·66
Aug. 26	1· 19·75
Sept. 5	1· 19·78
Mean	1· 19·86 ± ·05

Some slight improvement might be made in this determination by correcting for the difference between the error of the Greenwich sidereal standard clock found from the whole of the observations made and the error assumed when setting the mean time clock at 1 P.M. This difference, however, can hardly be of a systematic nature.

Corresponding to each of these days, complete observations for local time were obtained at Harrow on the nights immediately preceding and following the comparisons of the clocks. The rate of the Harrow transit clock is very steady. This longitude of course contains the relative personal equation between Colonel Tupman and the Greenwich standard observer; it is therefore the proper quantity to apply to Harrow time to obtain Greenwich time in the cases of occultations or transits of the Moon. Forty-five occultations of stars by the Moon have been observed, two-thirds of which have been compared with Hansen's Tables by the method employed at Greenwich.

The equatorial reflector has been chiefly used on observations of comets, generally with a ring micrometer, the instrument not yet being provided with a position circle. Owing to weakness of the declination axis, or possibly of the entire mounting, the

reflector can only be used on calm nights. A new and very much stronger declination axis is being made. Comet 1885 Barnard No. 1 was observed for place on two nights; Brooks No. 1 on four nights; Fabry eleven nights; Barnard No. 2 four nights.

The weather from the beginning of October to the end of January has been exceptionally cloudy. Only ten transits of the Moon could be obtained during those four months.

Royal Observatory, Cape of Good Hope.

The present report includes the period 1885, January 1 to December 31.

During the current observations of the preceding year it became evident that the disintegration of the inner surfaces of the crown and flint lenses of the object-glass of the Transit Circle (already considerable in 1879) was rapidly increasing. An amount of false light in the field was thus created which rendered it almost impossible to observe stars below the first magnitude by daylight. Thus the value of the observations of the sun was greatly diminished.

Observations with the Transit Circle were accordingly discontinued on February 8, and the object-glass was sent to Messrs. Troughton & Simms to be repolished. It was returned to the Cape on August 20, and immediately remounted. Observations were resumed on August 24.

Observations with the Transit Circle have thus been limited to twenty-four weeks of the year, the total work being as follows:—

Number of determinations of collimation	22
,, ,, level	156
,, ,, Nadir Point	126
,, ,, runs	127
,, ,, horizontal flexure	15

	Direct.	Reflex.
Number of observations of stars in R.A. ...	1401	243
,, ,, ,, N.P.D. ...	918	261

	Direct.	Reflex
Observations of both limbs of Sun in both elements	21	12
Observations of Mercury in both elements ...	13	7
,, Venus ,, ...	18	10

Advantage was taken of the necessary repolishing of the object-glass to have new steel screws (in lieu of the worn bronze screws) fitted to the microscopes of the Transit Circle. At the same time the order of the numbering of the graduations of the

drums of three of the microscopes was reversed, so that these microscopes might be turned 180°. Thus (as now at Greenwich) the wear of the screws produced opposite effects in the readings of each alternate microscope. The investigation of the new screws, although not yet complete, proves that their errors are very small.

Whilst the Transit Circle was idle one of the portable Transits by Troughton & Simms of 3 inches aperture was employed partly in an independent determination of the Right Ascensions of certain zones of stars for comparison with the results of the Transit Circle, and partly in exchanging telegraphic signals with Capt. Morris, R.E. (in charge of the field work), for determination of the astronomical longitude of points on the Geodetic Survey of South Africa, and in comparison of the personal equation of the observers with that of Capt. Morris.

For these purposes there have been made with the 3-inch Transit—

Determinations of collimation and level	304
Transits of stars	2433

Much time and labour have been bestowed upon perfecting the working and studying the constants of the Great Indian Theodolite. The investigation of the Pivot Errors from the construction of the instrument has presented great difficulties, but these have now been overcome, although the work is not yet quite complete.*

The errors of the screws (in some cases considerable) are fully investigated, and the corrections tabulated. From the fact that a different zero of the Horizontal Circle is employed on each night of observation it is not yet determined whether it will be necessary to completely investigate the errors of its graduation.

* The comparatively small diameter of the pivots (about 1 inch) does not permit the employment of the axis as a revolving collimator, according to Airy's elegant method. The utmost efforts of Mr. Simms did not succeed in engraving a perfect dot, at least one whose image would be beyond suspicion of change in its apparent centre, whilst its co-ordinates are measured at symmetrically arranged readings of the vertical circle. (An error of eccentricity in the position of the dot is of no consequence so long as the errors of the screw of the watch microscope are known or eliminated.) Such errors were partly, or perhaps completely, eliminated by reversing the dot-holder 180° between alternate sets of measures, but there remained some uncertainty which it was considered desirable to remove. Acting on a suggestion of Captain Morris, the experiment was made of grinding a particle of mercury in a drop of Canada balsam dissolved in ether, between two sheets of thin glass, such as that employed for covering microscope slides. In this way the mercury is subdivided into minute and exquisitely perfect spherical globules, which become firmly cemented between the glass plates when the Canada balsam has set. The small double plate of glass is then cemented on the end of the pivot and illuminated through the perforation of the pivot opposite to the watch microscope, and it becomes easy to find a perfect dot near the axis of rotation.

The values and inequalities of the two delicate ether levels, by which the inclination of the horizontal axis is determined, have been investigated. It was also found that the levelling of the instrument was very imperfect, the zero of the frame levels being different to the extent of several seconds of arc, according to the direction of rotation. This discordance was traced to imperfect fitting of the revolving part on the lower flange of the fixed vertical cone. The bearings were re-ground by Mr. Gill, and finally a perfect fit and perfect results in levelling were obtained after a fortnight's labour. It is noteworthy, however, that when observations are made in reverse positions of the instrument, the resulting azimuth is free from errors due to this cause if the levels are read simultaneously with (*i.e.* immediately before and after) the observation in each position. The only inconvenience is the increased difficulty of determining the level zero.

At first there was some instability in the relative azimuths of the meridian marks (in focus of and 150 ft. distant from lenses to N. and S. of the instrument), probably because the foundations of the four recently built piers had not had sufficient time to settle. For the last three months, however, the relative azimuth of N. S. mark has not changed half a second of arc.

Secondary batteries have been employed with great success for the incandescent lamps which illuminate the circle microscopes and the field of view. These batteries are charged once or twice a week by six Grove cells arranged in series of three. It is impossible to over-estimate the advantage of this method of illumination; its perfect freedom from flickering in the highest wind, its perfect constancy, perfect control, perfect cleanliness, and the comparatively small amount of heat given off, combine to increase the accuracy and ease of working in a manner that can only be fully appreciated by trial.

The complete working out of all details, the preparation of working forms, selection of stars and necessary preliminary computations, delayed commencement of definitive observations till September 1. Since that date the following observations have been made:—

Number of observations of meridian marks	129
Number of azimuths of circumpolar stars at elongation ...	210
Number of azimuths of northern stars for latitude by Kapteyn's method	63

The results appear to be very satisfactory.

A fundamental latitude is being determined by Prof. Kapteyn's method ("Copernicus," vol. iii. p. 147). The declinations of circumpolar stars are determined by observing azimuths of greatest elongation. Declinations of northern stars will be determined by connecting them by Talcott's method with

those of southern stars determined as above. In this way it is hoped that a new and trustworthy system of fundamental declinations, entirely independent of refraction, will be established.

Comet 1884 Wolf has been observed on eleven nights between January 7 and February 14; and Comet 1885 Barnard on six nights between July 12 and August 3.

An unsuccessful search was made for Biela's Comet after the meteoric shower of November 27; but the weather in the early mornings was cloudy for a week after that date, so that the most favourable opportunity was lost.

The observations of Comets Pons-Brooke, Barnard, and Wolf, made in 1884, have been communicated to the *Monthly Notices* and the *Astronomische Nachrichten*. The places of comparison stars for Comet I. 1881, which were observed at the request of Dr. E. von Rebeur have been communicated to the *Astronomische Nachrichten*.

A paper containing the results of observations of the Great Comet of 1882, with drawings of the nucleus and photographs of the comet, has been prepared. The sheets have been passed through the press by Mr. Finlay during his leave of absence in England, and will probably be ready for distribution before this report is published.

The results of observations of stars with the Transit Circle from 1879 till the repolishing of the object-glass are being formed into a catalogue for the Equinox, 1885. A working list for a new catalogue (Epoch 1890), containing 2,500 stars, has been prepared. It is intended that the observations for the new catalogue shall extend over ten years, and one of its principal objects will be to connect the system of declinations determined with the Great Theodolite and the equal altitude instrument, with the systems of the various Ephemerides.

Aided by a vote of 300*l.* from the Government Grant Fund of the Royal Society, the services of Mr. C. Ray Woods have been secured as photographic assistant.

The objects which induced H.M. Astronomer to apply for this aid were—

1. The desirability of securing, as soon as possible, a *Durchmusterung* of the southern heavens, since the photographs of the Great Comet of 1882 obtained at the Cape had proved the practical possibility of doing this work by direct photography from the sky.
2. The method of Dr. Huggins for photographing the Corona without an eclipse appeared to offer a new and interesting field of study.

The first of these objects has made very satisfactory progress. Mr. Dallmeyer had most generously lent one of his beautiful rapid rectilinear combinations, composed of two concavo-convex achromatic combinations of 6 inches aperture. This was

mounted in a strong square wooden tube attached to the declination axis of a powerful equatorial stand belonging to H.M. Astronomer (the stand of his Heliometer). A telescope of $3\frac{1}{2}$ inches aperture and 45 inches focal length is used as a guiding telescope.

Mr. Woods reached the Cape on February 19; the star photographs were begun on April 2. The following amount of work has been secured :—

	No. of Plates.
Perfectly successful plates (exposed an hour in clear sky) ...	209
Interrupted by clouds shortly before an hour's exposure, or otherwise slightly defective, but still useful	41
Lost by cloud or chemical faults	35
	285

Each plate is 6 inches square, covering an area of about 36°. A large overlap is provided for, and every area is photographed twice, so as to render it impossible to confound the images of faint stars with minute dust-specks. In this way the whole sky, from declination 63° to 90°, has been photographed in duplicate, excepting the area from R.A. 5^h to 8^h, which latter will be completed before the end of February, besides a considerable portion of the next zone. The zones are 5° apart.

From similar photographs taken near the equator and compared with Argelander's *Durchmusterung* it is evident that these plates show all stars to $9\frac{1}{2}$ magnitude.

Steps for commencement of the measurement, reduction, and cataloguing the work are under consideration.

In order to obtain without additional labour (beyond that of development of the exposed plates) pictures showing stars of 12th and 13th magnitude, for discussion of the distribution of stars according to magnitude, and also for the photographing of special areas such as those of dense clusters, it was desirable to obtain a more powerful optical apparatus.

On mentioning the matter to Mr. James Nasmyth, he most generously placed the funds necessary for purchase of a "Nasmyth lens" in the hands of Dr. Huggins, by whom a specially corrected photographic objective of 9 inches aperture and 9 feet focal length was ordered from Mr. Grubb. Plans for the mounting of this lens, together with a powerful guiding telescope and an improved Dallmeyer apparatus, have been prepared by H.M. Astronomer, and are under construction by Mr. Grubb.

The field of the Nasmyth lens will be much more limited than that of Dallmeyer's apparatus, but one should obtain from it by simultaneous exposure a photograph of all stars to the 12th or 13th magnitude within a radius of 1° or $1\frac{1}{2}$° of the centre of each *Durchmusterung* picture, and this will afford sufficient data for any general discussion of star distribution.

On account of delays from transhipment and other accidents the Coronograph did not reach the Cape till the end of June.

Many alterations had to be made to remove instrumental defects, so that the first of the series of pictures was not obtained till July 20.

There seems little doubt that true pictures of the Corona have been obtained, but H.M. Astronomer prefers to defer expression of a definite opinion till the apparent changes which he believes to have noted have been confirmed beyond doubt. Meanwhile the pictures have been sent to England, and a series of drawings is being prepared from them by Mr. Wesley.

An active correspondence has been maintained with Messrs. Repsold, of Hamburg, in reference to details of the new Heliometer.

The new Record Room (forming the foundation of the Heliometer Observatory) has been completed with the exception of some internal fittings.

The framework of the new observatory should reach the Cape before the middle of 1886, and the whole be fitted up ready for the reception of the new Heliometer, before the end of that year.

The Geodetic Survey of South Africa makes rapid progress.

An arc of latitude $3\frac{1}{2}^\circ$ in length has been completed in Natal; it includes astronomical latitudes and azimuths at three points, and three astronomical longitudes determined by exchange of signals with the Cape Observatory. Each longitude rests on exchanges on at least four nights, with time determinations at both ends. Captain Morris after these operations compared personal equation with the Cape observers on eight nights. The stars employed in the Talcott latitude observations are all included in the Cape observing list. Rapid progress is being made in extension of the triangles from Natal through Griqualand East to Port Elizabeth.

The absence in England, first of Mr. Pett, and afterwards of Mr. Finlay, on well-earned holiday, together with a large variety of work requiring his close personal attention, have prevented so much progress being made by H.M. Astronomer in the reduction of the Victoria and Sappho observations as would otherwise have been the case. It is expected, however, that the work will be completed during 1886.

During the present financial depression at the Cape it has not been considered desirable to press for funds for reduction of the Tidal Observations; the Admiralty has decided that the cost properly lies with the Colony.

The meteorological observations made in the year 1884 at the Observatory, together with those taken in different parts of the Colony, have been printed in the Reports of the Cape Meteorological Commission.

Hong Kong Observatory.

The new time-ball was dropped daily at 1 p.m. since January 1, 1885—Sundays and holidays excepted, as well as some days on which severe thunderstorms interfered. During a portion of September the time-service was interrupted, owing to fever among the staff. The ball is dropped automatically by the mean-time clock, which is electrically set to correct time by comparison with the sidereal standard clock, by aid of which also chronometers are rated. The errors of this clock have been tabulated and discussed up to date, and the temperature coefficient has been determined.

Transits of time stars and of some stars of southern declination, as well as of *Polaris* (for determination of the azimuth) and of the moon, were observed, and with the Lee Equatorial phenomena of *Jupiter's* satellites and a few micrometric measures were secured. The *Andromedes* were observed on November 27.

Absolute magnetic observations were made monthly, but the automatic tide-gauge has not yet been mounted and worked for want of funds.

The self-recording meteorological instruments were continuously marked, and the readings tabulated. Daily weather reports based on telegraphic information and storm warnings were issued. The complete monthly reports are published up to September inclusive. In these reports the observations made at the high-level station on Victoria Peak are also published.

Meteorological instruments of approved pattern have been verified and forwarded to the treaty ports and lighthouses in China, and the observers have been instructed. Their observations have not been reduced and discussed for want of funds, but have, in connection with abstracts of ships' logs, enabled complete investigations of typhoons to be carried out.

The first annual volume was published early last summer.

Notes on some Points connected with the Progress of Astronomy during the past Year.

Discovery of Minor Planets.

The following nine minor planets were discovered in the year 1885:—

No.	Name of Planet.	Date of Discovery, 1885.	Discoverer.	Place of Discovery.
245	Vera	Feb. 6	Pogson	Madras
246	Asporina	Mar. 6	Borrelly	Marseilles
247	Eukrate	Mar. 14	Luther	Düsseldorf
248	Lameia	June 5	Palisa	Vienna
249	Ilse	Aug. 16	Peters	Clinton
250	Bettina	Sept. 3	Palisa	Vienna
251	Sophia	Oct. 4	,,	,,
252	Clementina	Oct. 27	Perrotin	Nice
253		Nov. 12	Palisa	Vienna

Minor planet No. 244, discovered by Herr Palisa on October 14, 1884, has been named *Sita*.

The Comets of 1885.

Six comets have been discovered during the year 1885, including the periodical comet of Tuttle. These are noticed in order of discovery.

I. A comet discovered by Mr. Barnard, of Nashville, on July 9, presenting a circular appearance of about one minute in diameter, and as faint or fainter than a star of the 11th magnitude. At the time of discovery the comet was south of the Equator and moving southwards. Predicted positions, computed from elements derived by Dr. Lamp, were telegraphed to the southern observatories, where the comet, growing gradually fainter, was seen up to August 15. The orbit does not differ sensibly from a parabola, but the elements are remarkable, since they exhibit a perihelion distance greater than that of any other comet with the exception of that of 1729.

II. A suspicious object was seen on August 31 by Mr. Brooks, of Phelps, N.Y., which on September 2 proved to be a comet. This appears to have been independently discovered by Mr. Common at Ealing on September 4. The appearance was that of an ordinary telescopic comet with some central condensation. This comet had passed its perihelion passage some three weeks before its discovery, and was gradually growing fainter, and since its path was well represented by parabolic elements the comet possessed but little interest. The best elements appear to be those due to Dr. Oppenheim.

III. The periodical comet of Tuttle, which seems to have been systematically sought for and continuously observed only at the observatory at Nice. The perturbations of this interesting comet of fourteen years' period, and the preparation of an ephemeris for its approaching apparition, were undertaken by Dr. Rahts, of Königsberg; but unfortunately the circumstances of its return were not favourable to observation, and it is fortunate that MM. Charlois and Perrotin have succeeded in making a series of observations, though it extends only from August 8 to August 22. M. Perrotin reports that the observation of the comet presents great difficulty, owing to the feebleness of its light and its small altitude above the horizon during the ten or fifteen minutes before sunrise, during which alone the observation is possible. Professor Lewis Swift speaks of the comet as fairly bright in a dark sky, but his observations of the place have not yet been published. Theoretically, the comet had about one-third the brilliancy it possessed when first observed on its previous return in 1871. The observations of MM. Charlois and Perrotin show that the predicted place was in error by about $12^{s}\cdot6$ in R.A. and $5'\ 36''$ in declination, which discrepancies between the observed and computed place could be satisfactorily removed by corrections to the mean anomaly and mean motion of $42''$ and $0''\cdot00852$ respectively. This agreement is very satisfactory, as establishing the correctness of the mean motion in the elements derived by Dr. Rahts from the 1858 and 1871 observations, as well as of the effects of the perturbations in the interval 1871–1885, the publication of the complete discussion of which was delayed till after the observation of the comet.

IV. Discovered by M. Fabry, of the Paris Observatory, and originally reported as a faint object with nucleus, but subsequently described as a tolerably bright object, with well-pronounced stellar nucleus of the brightness of a star of the 11th magnitude. The perihelion passage does not occur till next April, and the determination of the elements by the method of Olbers is not unaccompanied

with difficulty. The best elements at this date are probably those of Dr. Oppenheim, which embrace twenty-five days' observation; but he reports that an error in the determination of the ratio of the curtate distances at the first and third observation occasions nearly three and five times the same error in the radii vectores of the comet at the same dates respectively, the middle observation being at the same time fairly well represented.

V. A comet discovered by Mr. Barnard, of Nashville, on December 3, and described as tolerably bright, but somewhat fainter than that of Fabry. The elements are not yet determined with precision, but the approximate orbit has great resemblance to that of the second comet of 1785. Dr. Hepperger has given elliptical elements with a period of 101·1 years, but the deviations of the path from either the ellipse or the parabola are not yet sufficient to decide the question of identity. As in the comet of Fabry, the orbit is nearly perpendicular to the ecliptic, and its discovery precedes its perihelion passage by some months.

VI. On December 26 Mr. Brooks, of Nashville, discovered another comet, which, however, is scarcely likely to prove interesting, since the comet at the time of its discovery was moving away from both the Sun and the Earth, and the elements do not coincide with those of any comet previously computed nor show signs of any ellipticity.

In addition to these observations, it may be as well to remark that Tempel's comet (1867, II.) approached the Earth last spring (being its fourth appulse since its elliptic character became known) without being detected. The position in the sky was not favourable for observation, and the continued perturbations of *Jupiter*, which in this comet may be excessive, have, on the whole, tended to make its observation more and more difficult. M. Gautier has discussed its path with apparently great care (the details are not yet published), and has given osculating elements for April, 1885, which show that a diminished excentricity has been accompanied by an increased axis major, and that the passage through the perihelion has been delayed no less than 148 days.

A comparison between the elements of the comet in 1867 and those computed by M. Gautier for its appearance in 1885 well illustrates the difficulty of deciding on the identity of two comets, simply by a comparison of their orbits derived from the observations during the time of the comet's visibility.

Another fact to which it seems desirable to call attention is the return of Olbers' comet, for which Dr. F. K. Ginzel has prepared extensive sweeping ephemerides. The most probable date for its return is December 17, 1886, but since the uncer-

tainty in this date amounts to ± 1·6 years, systematic searching for the comet is now desirable.

Dr. Galle has published in the *Astronomische Nachrichten* a catalogue of the orbits of recently-observed comets, as well as of those which have been improved by the more careful discussion of ancient observations. This is likely to prove a valuable and welcome contribution to cometary literature. The catalogue is really a continuation of that given in the third edition of Olbers's *Methode zur Berechnung der Cometenbahnen* (1864), apparently prepared, or at least now published, at the express solicitation of the editor of the *Astronomische Nachrichten*. It commences, however, in 1860, and in an approximate form gives the most accurate orbit of each comet that has appeared within the quarter of a century ending in 1884, together with the period of visibility and the length of time over which the observations employed in deriving the elements extend. From this list a computer can easily see what orbits have been definitely determined, and of what comets further discussion is likely to be useful. In the accompanying notes are short descriptions of and references to the original authorities where comets have been observed, but not a sufficient number of times to enable the elements to be determined.

It is statistically interesting to notice that the number of comets for which orbits have actually been computed up to the end of 1884 is 302, and of these twelve have proved themselves periodic, and have actually been re-observed more or less frequently at subsequent returns. Taking these into account, the number of computed orbits occasioned by cometary discoveries is 357. In the quarter of a century under immediate consideration 94 have been computed, while the number of improved orbits is 42. W. E. P.

Mr. G. W. Hill on the Lunar Inequalities due to the Ellipticity of the Earth.

It is well known that M. Delaunay was unfortunately prevented by a premature death from completely carrying out his purpose of determining all the sensible inequalities of the Moon's motion by means of his very original and beautiful method of treating that subject. Happily the two magnificent volumes in which he determines the inequalities which are caused by the disturbing force of the Sun, on the supposition that the motion of the Earth about the Sun is purely elliptic, are complete in themselves. The small effects due to the action of the planets and the spheroidal figure of the Earth, as well as those which arise from the disturbances of the Earth's motion, remained to be determined.

Mr. G. W. Hill, who is already well known for his skilful treatment of special portions of the lunar theory, has, in the

paper now to be noticed, produced a valuable supplement to Delaunay's work by applying the same method to the determination of the lunar inequalities which are due to the ellipticity of the Earth. This paper forms part ii of vol. iii. of the valuable series of astronomical papers prepared for the use of the *American Ephemeris* and *Nautical Almanac*.

The author first develops the terms of the disturbing function which are introduced by the ellipticity of the Earth, by substituting for the Moon's coordinates their disturbed values as already given by Delaunay's work. Some idea of the length and complexity of this substitution may be formed when it is stated that the development so obtained contains one constant term accompanied by 121 periodic terms.

The next process is by a series of transformations of the variables involved gradually to remove these periodic terms from the disturbing function, so that it is at length reduced to the form of a constant term.

The number of such operations required to effect this reduction amounts to 103, although each operation is individually sufficiently simple.

By the essential principle of Delaunay's method the differential equations throughout these transformations always preserve their canonical form, and therefore when the disturbing function has been reduced to the above-mentioned simple form, the integrals are at once obtained.

In the next place the transformations indicated in the 103 operations above mentioned are also made in Delaunay's expressions for the three coordinates of the Moon, so that finally the values of these coordinates are found in terms of three arbitrary constants and three angles, each of which consists of a term proportional to the time joined to an arbitrary constant.

The coordinates thus expressed are the longitude, the latitude, and the reciprocal of the radius vector. As this last quantity is only intended to be employed in finding the Moon's parallax, it is given by Delaunay with much less precision than the other two coordinates, a circumstance which is to be regretted as an imperfection from a theoretical point of view.

The expressions thus found are purely analytical, that is the coefficients are expressed in series of powers and products of Delaunay's constants m, e, e', γ, each term also involving as a factor a constant quantity which depends on the figure of the Earth.

In order to make his work more complete, Mr. Hill determines the numerical value of this last-mentioned factor by a very elaborate discussion of the results of numerous pendulum expements.

Finally, by the substitution of the known values of the constants employed, the numerical expressions for the perturbations of the Moon's coordinates produced by the figure of the Earth are obtained.

It may be remarked that comparatively few of the coefficients so found amount to an appreciable quantity, by far the larger number being utterly insensible.

The quantity m denoting, as in Delaunay, the ratio of the mean motion of the Moon to that of the Sun, it is found that the analytical expressions of most of the coefficients involve negative powers of m. This circumstance, which never happens in the case of the perturbations due to the Sun's action, has given rise to a difficulty in some minds as to the admissibility of Mr. Hill's results. Mr. Stockwell, in particular, in an article in the twenty-ninth volume of the *American Journal of Science*, asserts that the value given to the coefficient of the principal equation of latitude leads to a manifest absurdity, and "justifies the suspicion that the entire solution is erroneous."

The difficulty thus noticed by Mr. Stockwell, however, admits of an easy explanation. He applies Mr. Hill's formulæ to a case in which they are not applicable, and for which they were not intended. The form of development in series adopted by Mr. Hill is founded on the supposition that the perturbations due to the Earth's figure which he wishes to determine are very small compared with those due to the action of the Sun, and therefore he expressly neglects quantities which are proportional to the square of the first-named perturbations. Now, in the case of our Moon, which is that treated by Mr. Hill, the above-mentioned supposition certainly holds good, and consequently his formulæ are sufficiently accurate.

If, however, the Sun's distance from the Earth were very much greater than it is, or if the Moon's distance were very much less than it actually is, then the perturbations arising from the Earth's figure might be much greater than those which arise from the Sun's action, and a different form of development would have to be adopted.

In this latter case it would be better to refer the motion of the Moon, not to the ecliptic, but to a fundamental plane passing through the line of intersection of the equator and ecliptic, and occupying a definite intermediate position between those two planes. If the perturbations due to the action of the Sun are much greater than those due to the Earth's figure, this fundamental plane nearly coincides with the ecliptic, whereas if the latter perturbations are much greater than the former, the fundamental plane nearly coincides with the equator. In Mr. Hill's formula, the principal term in the expression for the latitude nearly represents the distance of the fundamental plane from the ecliptic corresponding to the actual longitude of the Moon at any time.

A simple analytical illustration of the change of form of the coefficient of this term of the latitude in different circumstances may be given.

If m have its usual meaning as before stated, and if c be a small positive constant depending on the ellipticity of the Earth,

then the value of the coefficient in question is approximately proportional to

$$\frac{c}{m^2 + c}$$

Now if, as in the case of our Moon, c is very much smaller than m^2, so that we may neglect the square of c compared with that of m^2, the quantity just mentioned becomes approximately $= \frac{c}{m^2}$; whereas if m^2 is small compared with c, the same quantity becomes nearly $= 1$, and the co-efficient becomes nearly independent of the ellipticity of the Earth, as it should do, since in this case the coefficient of this term is approximately equal to the sine of the obliquity of the ecliptic.

Mr. Stockwell's second objection, that Mr. Hill has omitted to take into account the modification of the Sun's disturbing force which is caused by the alterations of the Moon's coordinates due to the ellipticity of the Earth, seems to arise from a misapprehension on his part of the spirit of Delaunay's method. These alterations of the Moon's coordinates are implicitly involved in the variables a, e, γ, l, g, h, throughout the series of operations by which Delaunay gradually removes from R the periodic terms arising from the action of the Sun.

Professor Asaph Hall's Researches on the Orbits of Satellites.

In Appendix I. to vol. xxviii. of the "Washington Observations" Professor Asaph Hall discusses the observations of *Oberon* and *Titania*, the two outer satellites of *Uranus*, made by himself with the great 26-inch refractor of the Washington Observatory during the years 1875, 1876, and 1881–1884.

The apparent position of the orbits was then suitable for a good determination of the node and inclination, and the main results of this discussion are what appear to be very accurate values of these elements, and of the apparent mean distances of the satellites, and consequently a trustworthy value of the mass of *Uranus*.

If N denote the place of the node, and J the inclination of the orbits on the equator of 1883, the values found for these elements are—

$$N = 165^\circ 8$$
$$J = 75^\circ 3$$

Also the mass of *Uranus* $= \frac{1}{22682}$, that of the Sun being unity.

The author thinks that this value of the mass is smaller than any found before, but it may be remarked that a still smaller

value, viz. $\frac{1}{24605}$, was found many years ago by Professor Lamont, of Munich.

Appendix II. to the same volume of the "Washington Observations" contains a similar discussion of the observations of the satellite of *Neptune*, made with the great Washington refractor by Professor Hall himself in the years 1875–1877 and in 1881–1884, and by Professor Holden in the years 1874–1878, and also the observations made at Malta by Messrs. Lassell and Marth in the years 1863 and 1864.

The resulting place of the node and the inclination of the orbit to the equator of 1883 are—

$$N = 184^{\circ}3$$
$$J = 120^{\circ}0$$

Also the mass of *Neptune* resulting from the observations of Lassell and Marth is $\frac{1}{17850}$, whilst that which results from Professor Holden's observations is $\frac{1}{18279}$, and that from Professor Hall's own observations is $\frac{1}{19092}$, that of the Sun being 1.

Appendix I. to the "Washington Observations" for 1882 contains an elaborate investigation of the orbit of *Japetus*, the outer satellite of *Saturn*, also by Professor Hall. The observations employed were made with the great Washington refractor. The observations consisted partly of measurements of differences of right ascension and declination of *Japetus* and the planet, and partly of measurements of angle of position and distance, made by Professor Hall himself between the years 1875 and 1884, and likewise included similar observations made by Professor Newcomb in 1874.

These observations are compared with the elements of the orbit given by M. Tisserand in the first volume of the Annals of the Observatory of Toulouse, and equations of condition for the correction of the elements are formed from them and then solved in the usual way. The periodic time is corrected by comparing these observations with one made by Sir W. Herschel in 1789, and with the observations of Sir John Herschel at the Cape of Good Hope in 1837.

Professor Hall then proceeds to calculate the principal perturbations of *Japetus* which are due to the action of the Sun, confining his attention to the secular perturbations, and to such periodical perturbations as are independent of the position of the satellite in its orbit.

He also calculates the value of an inequality of long period in the motion of *Japetus* caused by the action of *Titan*, the exist-

ence of which was pointed out by Plana, and which arises from the fact that five periods of *Titan* are nearly equal to one of *Japetus*.

The following are the elements of the satellite's orbit which result from the observed differences of right ascension and declination in the oppositions of 1875, 1876, and 1877 :—

Epoch 1876, Sept. 20·5, Greenwich Mean Time.

Mean Longitude	$E = 7^\circ\ 35'\ 9''.8$	Referred to the ecliptic and the mean equinox, 1876·0.
Perisaturnium	$P = 349\ 59\ 27''.8$	
Longitude of node	$n = 142\ 30\ 11''.7$	
Inclination	$i = 18\ 35\ 41''.1$	

Apparent mean distance $a = 515''.523$

Eccentricity $e = 0.02843$

The following are the elements found from the angles of position and the distances observed from 1876 to 1884.

Epoch 1880, March 17·0, Greenwich Mean Time.

$E = 26^\circ\ 43'\ 2''.0$	Referred to ecliptic and mean equinox, 1880·0.
$P = 353\ 46\ 48''.2$	
$n = 142\ 34\ 23''.6$	
$i = 18\ 33\ 2''.3$	

$a = 515''.512$

$e = 0.02722$

Prof. Hall reduces these elements to the mean elliptic elements for 1876 and 1880, by deducting the periodical perturbations due to the Sun's action which he has calculated, and he also gives the numerical values of the secular perturbations of the elements due to the same cause; but since the secular perturbations due to the figure of the planet are very uncertain, while those due to the action of the Ring and of the other satellites are altogether unknown, the actual secular perturbations can only be determined by future observations.

The periodic time of *Japetus* is found to be 79·3310152 mean solar days.

Prof. Hall deduces the following value of the mass of *Saturn*, viz. $\frac{1}{3481\cdot3}$, that of the Sun being unity. This is slightly greater than that determined by Bessel, $\frac{1}{3501\cdot6}$, which is usually employed.

Finally he gives some tables which facilitate the calculation of elliptic places of the satellite.

Prof. H. G. van de Sande Bakhuyzen on the Rotation Period of Mars.

Professor H. G. van de Sande Bakhuyzen gives in a memoir now published separately, but which will form part of the seventh volume of the "Annals of the Leiden Observatory" a fresh discussion of the rotation period of *Mars*. An opportunity for such an investigation had been afforded by the acquisition in 1876 by the University of Leiden of the papers and drawings prepared by Schroeter for his projected great work on *Mars*. These were published, under Prof. Bakhuyzen's editorship, in 1881. In addition to the valuable observations thus placed at his disposal, Prof. Bakhuyzen was in the possession of considerably more material than had been in the hands of Kaiser, Proctor, or Schmidt, when they were engaged on the same discussion, since *Mars* was well and frequently observed both in 1877 and 1879.

The author's method of using his material has been as follows. Confining himself at first to a consideration of the drawings made during the oppositions of 1862 and 1864 by Kaiser, Lockyer, Lord Rosse, and Dawes, and adopting Schiaparelli's position—unquestionably very correct—for the north pole of *Mars*, he has ascertained the position of his assumed zero-meridian for the beginning of 1863, and found that it coincided with the Martial meridian passing through the Earth's north pole, on January 1, 1863, at $20^h\ 27^m\cdot0 \pm 4^m\cdot0$ Berlin M. T. The meridian adopted for the zero of longitude is very close to that selected by Schiaparelli, and lies 2° to the east of Mädler's point *a*. The next step was with Proctor's value for the rotation period—the one he published in 1869, viz., $24^h\ 37^m\ 22^s\cdot74$—to compute the areographic longitude for the centre of the disc for a number of dates for which we possess drawings of the planet. The drawings employed have been those of Huyghens for 1659, 1672, and 1683, of Hooke for 1666, Herschel 1777 to 1783, Schroeter 1785 to 1802, Beer and Mädler 1830, Schiaparelli, Lohse, Green, Niesten, and Dreyer 1877, and Schiaparelli 1879, besides those already mentioned for the oppositions of 1862 and 1864. The longitudes of a number of the most conspicuous spots were then determined; and from a comparison of these longitudes, a correction to the assumed rotation period has been derived, the resulting corrected period being $24^h\ 37^m\ 22^s\cdot66 \pm 0^s\cdot0132$, or $0^s\cdot08$ less than the one adopted from Proctor. It seems clear that this new value, which is very nearly the mean of the best previous determinations, is an improvement even on the very close approximations we possessed before.

Prof. Bakhuyzen adds a brief note on probable changes on the surface of *Mars*. He considers that it is highly probable that "Huggins Inlet," or the "Cyclopum" canal in Schia-

parelli's nomenclature, and perhaps Schiaparelli's canal "Læstrygonum" were much more conspicuous objects at the time when Schroeter made his observations than they have been during recent oppositions. The evidence with regard to the "Cyclopum" canal certainly appears very strong.

A table for inferring the time of coincidence of Prof. Bakhuyzen's adopted zero-meridian with the Martial meridian passing through the north pole of the earth for any date during the present century, and another giving the angular rotation-motion of *Mars* corresponding to any number of hours or minutes, conclude the memoir. E. W. M.

The Cape Catalogue for 1850.

A catalogue containing the places of 4,810 stars for the epoch 1850 has been published by Dr. Gill. It contains the results of observations made at the Cape Observatory during the years 1849-52, under the superintendence of the late Sir T. Maclear. The R.A.'s were all observed with Dollond's transit of 5 inches aperture, which was mounted by Fallows in 1828. The N.P.D. observations were made with Jones's 6-foot mural circle, with 4-inch object-glass, erected in 1839. The stars whose places are given in this catalogue are stars of the British Association Catalogue south of the equator. Apart from some discussions arising from attempts to reconcile the observations of Lacaille and others with the results obtained at the Cape (published in the *Memoirs*, vol. xx.), the reductions were left in a very incomplete state until they were taken up by Mr. Stone, who pushed them on as opportunity offered during his years of office at the Cape, about half of the reductions to mean place having been made under his direction. The clock errors used in the reduction of the R.A. observations were obtained from observation of *Nautical Almanac* stars. Certain corrections have been applied to the N.A. places of these stars, taken from a table prepared by Mr. Stone. This table is printed in the introduction to the catalogue. In the N.P.D. observations two microscopes only were as a rule employed, and there does not appear to have been any investigation of the errors of division. Dr. Gill, however, has drawn up a table of corrections, which approximately reduce the mean of two microscopes to the mean of six. The latitude adopted was $-33^\circ\ 56'\ 3''\cdot5$, and the refractions used were those of Bessel's Tabulæ Regiomontanæ. The index error of the exterior thermometer was assumed to be insensible, but strictly a correction of $-0^\circ\cdot27$ Fah. should have been applied. No corrections have been applied for flexure. No proper motions are given in the catalogue, and none have been applied to the star places. The corrections to mean place for the greater number of observations were computed with the aid of Mr. Stone's tables.

For the purpose of determining the systematic errors of this

catalogue, Dr. Gill has compared it with the Cape Catalogue for 1880. The separate results of the comparison for each star are given in the body of the work, the collected results being printed in the Introduction.* When proper motions are given by Mr. Stone in the 1880 catalogue, allowance for such has been made in the comparison; otherwise it is assumed that the accidental effect of proper motion will disappear from the mean of so large a number of stars, some 3400 in all. From this comparison it appears that the agreement in N.P.D. is not unsatisfactory, there being a practically uniform difference (within the limits of error of most of the separate N.P.D.'s) between the catalogues through the range of polar distance over which the observations extend. But the comparison in right ascension is by no means so satisfactory, as there are considerable discordances depending not only on R.A., but also on polar distance, which Dr. Gill appears to think may possibly arise from the non-reversible character of the Cape transit-circle, with which the observations contained in the 1880 catalogue were made, as in his opinion it is possible either that the collimation of the instrument may not remain constant at different altitudes, or, less probably, that the observations may be effected by lateral refraction caused by the non-symmetrical position of the wings of the building with respect to the instruments. At all events, Dr. Gill considers that there is more marked difference depending on N.P.D. between the R.A.'s of the Cape and Greenwich Catalogues for 1860, when non-reversible instruments were employed, than in the 1840 catalogues, when reversible transits were used at both Observatories. And a comparison of the R.A.'s of the Cape and Greenwich Catalogues for 1850 appears to Dr. Gill to bring additional evidence to show that the R.A.'s of the Cape Catalogue for 1850 may be accepted with considerable confidence. On the whole, however, Dr. Gill is inclined to think that the declinations of the catalogue must be considered superior to the right ascensions. The observations in R.A. have given a great deal of trouble; the work of one observer had to be entirely rejected, and that of another proved in some instances to be so bad that occasionally a whole night's observations have had to be rejected also. This naturally throws a certain amount of doubt on the accuracy of the right ascensions of the 1850 catalogue, and it is therefore not surprising to find that some astronomers have not been able to accept Dr. Gill's conclusions as to the results derivable from the comparison of the 1850 and 1880 catalogues. In the discussions which have

* There appear to be some numerical *errata* in the table on page xiv of the Introduction giving the comparison of the catalogues in N.P.D. arranged in groups of 4^h in R.A and 12° in N.P.D. The mean for the zone $138° - 150°$ of N.P.D. should be $+0''.70$ instead of $+0''.87$, and the number of stars 666 instead of 535. The mean for the group $8^{hs} - 12^{hs}$ of R.A., should be $+0''.24$ instead of $+0''.30$, and the number of stars 639 instead of 508. The general mean should be $+0''.45$ instead of $+0''.46$, and the number of stars 3535 instead of 3404.

been published on the subject two points have chiefly been dwelt upon: (1) that from our ignorance of the proper motions of southern stars it is impossible to compare catalogues whose epochs differ by as much as twenty-five years, so as to deduce any reliable results with regard to their systematic errors; and (2) that even if no considerable error is introduced from this cause, when such a large number of stars are used in the comparison, there is evidence, derived from comparisons with other southern catalogues, to show that the R.A.'s of the 1880 catalogue are probably superior to those of the 1850 catalogue. It would appear, therefore, that the discordances pointed out by Dr. Gill are not necessarily due to the causes which have been mentioned by him. In order to throw additional light on this subject, Dr. Gill proposes to observe a series of stars nearly simultaneously both with the transit instrument and the transit-circle, and points out that much interest will attach to a comparison of Mr. Stone's extensive catalogue with the great Cordoba Catalogue, in the observations for which Dr. Gould has employed a reversible transit-circle.

Apart from the discussion to which its publication has given rise, the Cape Catalogue for 1850 is a welcome addition to the published record of work done at the Cape Observatory.

Uranometria Nova Oxoniensis.

The important photometric researches of Professor C. Pritchard, conducted at the Oxford University Observatory, from the year 1881 to the present time, have culminated in the publication of a photometric survey of all stars visible to the naked eye from the North Pole to about 10° south of the Equator, which in more than one respect is unique in the history of astrometry.

Under the appropriate title of the "Uranometria Nova Oxoniensis," Professor Pritchard has given the results of some 70,000 instrumental measures, made with the wedge photometer, of the brightness of those visible stars whose magnitudes had been estimated by Argelander by eye observations, and published in his "Uranometria Nova" in 1843. While rendering a tribute to this former important work, Professor Pritchard truly remarks that the requirements and progress of modern astronomy demand greater exactitude than that which Argelander's work justly claims, and a precision exceeding any that can be expected from observations made with the unaided eye.

The work commences with a concise and interesting general historical survey of astronomy, with a brief reference to the various photometers which have been devised to determine stellar magnitudes, forming an epitome of the more extensive and important history of the subject given by the author in vol. xlvii. of the Society's "Memoirs."

The same memoir contains an exhaustive discussion of the theory of a neutral tint glass wedge. The fundamental principle on which the wedge photometer is constructed is enunciated thus in the work under consideration: "The light lost in passing through the medium measured by the alteration of magnitude is proportional to the thickness of the absorbing medium through which it has passed."

Two wedges, A and B, were employed in making the observations attached to two telescopes, one of 4 inches and the other of 3 inches; wedge A, $6\frac{1}{2}$ inches long, 1 inch broad, and 0·145 inch thick, tapering off to 0·02 inch; and wedge B, 4 inches long, 0·110 inch thick, tapering off to 0.02 inch. In wedge A the mean wedge interval required for the absorption of the light of one magnitude is 0.514 inch; in wedge B this interval is 0·385 inch.

The wedge is enclosed in a brass cellular rim with bevelled edges, one of which is divided into tenths of inches. It slides in a groove in the brass cap of the eye-piece of any telescope close to the achromatic eye-lens, and is thus placed between the eye of the observer and the telescope. In the focus of the eye-lens is a diaphragm pierced with a number of small holes, which vary from 0·01 inch to 0·25 inch in diameter, and in which small circular hole the telescopic image of a star is carefully placed, and there viewed through the wedge. Further, the eye of the observer is directed along the axis of the lens and of the telescope by means of an external eye-hole placed close to the wedge, and varying from one-twelfth of an inch to one-quarter of an inch. This direction of vision is important. A fiducial mark is drawn on the brass cap of the eyepiece, so that the position of the wedge can be distinctly marked and recorded when the image of the star is just extinguished by the wedge." The effect of this instrumental arrangement is that a star is viewed in a very small field of view; for instance, that of the 4-inch telescope employed is only about eighty seconds of arc in diameter, and the author claims in his discussion of the "freedom of the measurements from the influence of background," that by restricting the field of view by means of the diaphragm the influence of neighbouring bright stars is rendered insensible.

The method of using this photometer was to select about ten stars for a night's work, such that they could be observed at about the same altitude as *Polaris*. The standard star *Polaris* was extinguished at the beginning, the middle, and the end of the observations. The readings of the wedge were taken five times with the full aperture of both telescopes. A cap was then placed on each object glass, reducing the aperture to one-half, and five extinctions were again made, this second series of readings forming an excellent check upon the first. Thus were obtained for each star with wedge A five extinctions with apertures of 4 inches and 2 inches respectively; and with wedge

B the same number of extinctions, with apertures of 3 inches and 1½ inches.

Professor Pritchard gives a table showing the particulars of numerous repeated measures of sixteen selected stars, which reveals a very remarkable consistency in the observations and a very small mean error. The consideration of this table leads the author to the conclusion that after a certain number of observations nothing is gained in point of accuracy by the multiplication of observations. The mean error of a single extinction is 0·3 of a magnitude; the mean error of a single determination of magnitude as given by ten or twenty extinctions is under 0·1 of a magnitude.

Several sources of error in making observations are discussed by the author. To test whether the eye gets possibly fatigued during any considerable series of observations on any single night, comparison is made between sets of observations of *Polaris* made on separate nights, but without trace of a systematic difference. This is probably the experience of most of those who have worked in the same line. But consistency in the individual extinctions of stars can only be secured by preserving the eye in a normal condition of strain, for any additional effort of the eye will probably cause the star to be extinguished at a denser portion of the wedge. It would therefore have been more interesting and to the point if the author had compared consecutive observations made on the same night, rather than the mean of observations made on different nights.

Professor Pritchard has eliminated such probable errors by his admirable method of observation which secured for each star at least twenty separate extinctions, made with what virtually amounts to four different telescopes. The measures are strictly differential, the mean of the three sets of readings of the extinction of *Polaris* being used for all the observations of the series.

The results of this extensive and remarkable photometric work are contained in a catalogue in which the stars are arranged in constellations. The following particulars are given in the catalogue reference number: Star's Designation, Approximate Co-ordinates for the Epoch 1890, Adopted Zenithal Magnitude on the assumption of the magnitude of *Polaris* being 2.05, Average Deviation in Magnitude, Date of Observation, and the Magnitude in Argelander's "Uranometria Nova." The number of extinctions is not given, but it is presumably twenty for each star. The notes which are appended show, however, that the final magnitude of many stars depends upon a much larger number of observations made on different nights, the accordance between determinations made at wide intervals of time being very noteworthy.

The comparison of Professor Pritchard's star magnitudes with determinations by Professor Pickering and other observers shows satisfactory agreement in the majority of cases; and the

small values of the average deviation in magnitude suggest a remarkable consistency in the observations, and indicate the high value that must be attached to this photometry. The accomplishment within four years of so probably accurate a photometric determination of 2,784 stars visible to the naked eye from the Pole, to 10° south of the Equator, will always reflect honour on Professor Pritchard and his able assistants, Mr. W. E. Plummer and Mr. C. Jenkins.

Professor Pritchard's claims to the gratitude of astronomers will be more fully referred to in the President's address.

Dr. Müller's Sidereal Photometry.

Dr. Müller's photometric researches have been conducted entirely at Potsdam, and have been generally confined to the determination of the coefficient of atmospheric absorption. The observations extend over a period of four years, and have required some 36000 settings of the instrument. Dr. Müller's entire plan embraced, besides the determination of the extinction of light in the atmosphere, the measurement of the brightness of the larger planets and of a considerable number of the smaller, including also the variation of the light in interesting variable stars. Only the first portion of his programme is yet complete, and his investigation differs from that of Seidel in pursuing the enquiry in closer proximity to the horizon, and in giving special consideration to the influence of the extinction on coloured stars.

The Zöllner photometer employed was provided with two object glasses, one of 37·2 mm. and the other of 35 mm.; their focal lengths being respectively 393 mm. and 122 mm. Either aperture could be reduced by diaphragms to 31·0, 22·5, 15·0, and 9·0 mm., and the intensity circle could be read by verniers to $\frac{1}{10}$ of a degree. The colorimeter was supplied with a rock crystal plate (left-handed) 5·020 mm. in thickness.

Dr. Müller refers to the two disadvantages of the Zöllner photometer, viz. the want of constancy in the flames, and the appearance of the artificial star. The first of these disadvantages Dr. Müller believes he has eliminated by his frequent reference to *Polaris*; and, moreover, he contends he has kept the flame constant for five hours. He admits that the steady and somewhat dull light of the artificial star is a disadvantage when the artificial image is compared with stars, and is one which can only be partially removed by practice.

Experiments have been made, principally with the object glass of shorter focal length, to determine the amount of light lost by the introduction of the various diaphragms. The results are as follows:—

$$\log \frac{h^{\mathrm{i}}}{h^{\mathrm{iv}}} = 0{\cdot}3695,\ \log \frac{h^{\mathrm{ii}}}{h^{\mathrm{iv}}} = 0{\cdot}3439,\ \log \frac{h^{\mathrm{iii}}}{h^{\mathrm{iv}}} = 0{\cdot}2687,$$

the accents showing the diaphragms employed. The theoretically computed values are 1·0742, 0·7959, and 0·4437. Dr. Müller considers that this very striking difference between theory and fact might be attributed partly to the imperfection of the object glass employed, being of so short a focal length, and partly to the operation of the parallel plane glass plate through which the rays pass. With the second object glass the differences are not so conspicuous; and with a telescope of 135 mm. (5·3 inches) apertures the difference vanishes.

The examination of the instrument contains an elaborate determination of the brightness of certain stars in various positions of the colorimeter, compared with those of other observers, viz. Zöllner, Rosen, Ceraski, and Peirce. The result of the comparison, which is also exhibited graphically, shows that there exists a similarity of result among the various observers, but the agreement is by no means exact.

The stars selected for Dr. Müller's determination of the coefficient of absorption were *α Cygni*, *η Ursæ Maj.*, *δ Persei*, *α Aurigæ*, and *α Tauri*, the last added on account of its red colour, though its meridional zenith distance at Potsdam is 36°.

The constant of absorption was obtained for each star, and the mean result is "that the brightness of a star seen in the zenith is 0·8250, if the brightness of that star, without the existence of the atmosphere, be represented by 1." A table is given exhibiting for every degree of zenith distance down to 88° the corresponding atmospheric absorption.

The finally resulting zenith magnitudes of the afore-mentioned stars on the assumption of *Polaris*=2·05 mag., and compared with the Oxford and Harvard results, are as follows:—

Star.	Magnitude determined by Dr. Müller.	Adopted Magnitude at Oxford.	Adopted Magnitude at Harvard.
α Cygni	1·35	1·32	1·37
η Ursæ Maj.	1·91	1·77	1·92
δ Persei	2·98	3·11	3·08
α Aurigæ	+0·77	+0·92	+0·92
α Tauri	+0·10	1·12	+0·10

Herr Wolff's Sidereal Photometry.

Herr Wolff commenced his photometric work at Palermo, where he was compelled to pass the winter of 1869–70, and continued it at Bonn, with more or less regularity, as was unavoidable for a private observer, until April 27, 1875. The instrument made use of was a Zöllner photometer, of 37·5 mm. (1·5 inches) aperture, and of ·375 m. (14·8 inches) focal length. The result was the measurement of the light of 475 stars from the first to the sixth magnitude, but expressed not in magnitude,

but as logarithms of the light compared with that of the mean condition of his lamp, and actually as it burnt on Dec. 8, 1873. There was more recently published a further catalogue, carried on till March 5, 1883, making the total number of stars observed 1130. Herr Wolff, in his first publication, adopted Seidel's coefficient of atmospheric absorption without alteration; but in his more recent work he made some observations of his own for the determination of this constant. The result was ·234 mag. instead of Seidel's ·250 mag. Müller of Potsdam's coefficient is ·209 mag.; Pritchard's at Oxford ·253 mag.

There are two remarkable peculiarities in Herr Wolff's photometric determinations. The first is, that the observed quantity of light transmitted through varying apertures differs greatly from the theoretically computed quantity; and, secondly, the logarithms of the ratios of the lights for different stars, when converted into magnitude on a uniform scale, differ by a gradually increasing quantity, depending on the magnitude from all other investigations of this character. It is not easy to suggest a satisfactory solution of this second difficulty, but inasmuch as perfectly reliable results have been obtained from the Zöllner photometer by other astronomers, it would seem that the solution must be sought for in some subjective cause peculiar to this observer. Professor Pickering has endeavoured to remove what he regards as the systematic error in these researches, and reduces Herr Wolff's numbers to consistency with his own determination by the application of the corrections shown in the following table:—

Limits of Magnitude.	Reduction.	Limits of Magnitude.	Reduction.
mag.	mag.	mag. mag.	mag.
Brighter than +0·7	0·00	3·3 to 4·2	+0·60
+0·7 to +0·3	+0·10	4·3 to 4·7	+0·70
+0·2 to 1·2	+0·20	4·8 to 5·2	+0·80
1·3 to 1·7	+0·30	5·3 to 5·7	+0·90
1·8 to 2·2	+0·40	5·8 to 6·2	+1·00
2·3 to 3·2	+0·50		

Astronomical Photography.

The greater capabilities of photography, through the increased sensitiveness of the modern dry plate, in its application to astronomical work, become every day more apparent. The most recent successful results, particularly in stellar photography, have been obtained during the past year by MM. Paul and Prosper Henry, of the Paris Observatory. From an account by Admiral Mouchez in the *Comptes Rendus* of May 11, 1885, in which some of the results of the early trials of the new telescope are given, it appears that some experiments made in 1884, with an aperture of $0^{m}{\cdot}16$, decided them to make a larger instrument especially for photography, and in a very short time,

considering the work of calculation and actual making, an objective of $0^m{\cdot}34$ aperture and $3^m{\cdot}43$ focal length (this focal length was chosen to give one minute of arc to one millimetre) was made and mounted equatorially on the English form. Placed parallel to the photographic telescope, if such a term can be used, is a telescope of similar focus and $0^m{\cdot}24$ aperture, for the purpose of watching and directing the movement of the instrument, during exposure, by the ordinary means.

Work was begun in May, and the results have been most remarkable; their enumeration below will make it evident that the great expectations formed by the early workers in astronomical photography are about to be fully realised.

(1) Stars as faint as the fifteenth and sixteenth magnitude have been photographed, and plates of more than 2° each way of portions of the Milky Way, with from 30 to 60 stars down to the fourteenth or fifteenth magnitude to the square centimetre of plate; that is, from 1080 to 2160 to every square degree distinctly shown, with an exposure of one hour. On some plates three separate exposures of one hour each are given, the instruments being moved between each to change the position of the image on the plate and form a triangle about 5″ from point to point, so that accidental spots cannot be mistaken for faint stars—a most successful plan as far as the very faint stars are concerned. Enlarged paper prints of some of these plates have been received by the Society, but the fainter stars are not easily seen, nor, in consequence, the triangular arrangement.

(2) A nebula has been discovered in the *Pleiades*, near *Maia*, so very faint that it is doubtful if it has ever been seen, or would have been found otherwise; and, judging from a copy of the original negative published in *L'Astronomie* of Feb. 1886, the nebula near *Merope*, about which there has been so much discussion, is distinctly seen on the plate, whilst the small detached part lying between *Merope* and *Alcyone*, shown on a sketch by Mr. Common in the April number of the *Monthly Notices* for 1880 as having been seen with his 3-ft. reflector, is also distinctly shown. This opens out a possibility of finding nebulæ and charting them, as well as stars.

(3) A photograph of *Saturn* has been taken by direct enlargement of the primary image by means of a non-achromatic ocular giving a magnification of eleven times, which goes far beyond anything yet done in planetary photography, as can be seen from the paper prints that have been received. This photograph gives promise of most satisfactory results from the application of this method of direct enlargement of the primary image to planets, double stars, the Moon, and other objects.

(4) *Hyperion* has been photographed with an exposure of thirty minutes, and the satellite of *Neptune* can be taken in any part of his orbit as it is at present presented to us.

These are results that speak for themselves, and for which the MM. Henry are to be heartily congratulated, not only for the actual labour of working for them, but for the perfection of the optical part of the instrument, the work of their own hands.

In view of these remarkable results the remarks of Mr. Rutherfurd, one of the most successful of the early workers in astronomical photography, made now more than twenty years ago, may be worth repeating. He says in the *American Journal of Science*, page 308, vol. xxxix., after mentioning the construction of a lens specially made for photography, of $11\frac{1}{4}''$ aperture and 14 ft. focal length, "The power to obtain images of the ninth magnitude stars with so moderate an aperture promises to develop and increase the application of photography to the mapping of the sidereal heavens, and in some measure to realise the hopes which have so long been deferred and disappointed. It would not be difficult to arrange a camera box capable of exposing a surface sufficient to obtain a map of two degrees square, and with instruments of large aperture, we may hope to reach much smaller stars than I have yet taken. There is also every probability that the chemistry of photography will be very much improved, and more sensitive methods devised." Judging from the results that he then obtained, there is no doubt that it was entirely to the want of sensibility of his plates that stellar photography has been so much delayed, and that more will evidently be got from greater sensitiveness of the plate than from mere increase of aperture.

The extent to which accurate measurements of the positions of stars on the photograph can be carried becomes interesting in view of the many questions depending on such accurate measurements. The size of the image on the plate varies (with an equal exposure) according to the brightness of the star (neglecting any difference in colour), and with the telescope of MM. Henry and an exposure of an hour, images of stars of the 14th to 15th magnitude have a diameter of about one-thousandth of an inch—that is, equal in arc to about $1\frac{1}{2}''$. Stars of the 5th or 6th magnitude reach a diameter of about $1'$.

As far as can be seen, the growth of the image is quite concentric with the point of the plate on which the image of the star falls, and that a centre found by measuring from the edge of the image of a large star would be the actual centre, such as would be shown by a sufficiently short exposure. This is shown in a remarkable way in those photographs of MM. Henry where three exposures of one hour each are given, and the instrument moved so that the images of each star form a little triangle, as has been mentioned.

On looking at the faintest stars on the plate, they are seen as little groups of three. As brighter stars are examined it is found that the images increase, and at last go on till they overlap, and this goes on till the complete images of any one bright star are

very much larger than the original little triangle, but the appearance is as if three circles nearly as large as the resulting image had been struck from the centre of what would have been in the case of a smaller star the three stars of a group.

Whether it would not be better to take single exposures on one plate, and reserve this for comparison or measurement, taking a plate with three exposures for the purpose of identification, is a point that will be better settled by time. For stars of similar brightness, or within a few magnitudes of each other, the images not being much more than from ·001 in. to ·01 in. in diameter, thus being about $1\frac{1}{2}''$ to $15''$, the accuracy with which the distances of the centres could be determined might be safely put at from $\frac{1}{4}$ to $\frac{1}{8}$ of the smaller quantity; and by judicious enlargement and comparison the shift of the stars *inter se* could be detected by a much smaller amount.

In a letter published in the *Monthly Notices* for last November, Admiral Mouchez, writing under date of June 20, states that it is the intention to use this photographic telescope to continue their Ecliptic Charts, but he also suggests that, with the co-operation of six or eight observatories the whole heavens should be charted in a similar way. He states how this may be done, and it is to be hoped that he may be able to get such a desirable work done in the way he suggests.

At the Cape of Good Hope, as will be seen from the report of Dr. Gill, considerable progress has been made in getting a *Durchmusterung* of the southern heavens, but on a much smaller scale than that proposed by Admiral Mouchez. An instrument, slightly inferior in power to that of the Paris Observatory, is in course of construction for use, as mentioned in the report referred to.

Mr. Roberts, in England, has erected a reflector of 20 inches aperture, and 100 inches focus, for stellar photography, and made considerable progress in the work he has undertaken of charting the northern heavens by this instrument. Other observers contemplate this class of work, so that soon there will be a means of arriving at some opinion as to the best plan to follow in the future, both as regards the instrument, the plate, and the best scale for different investigations.

All the possibilities of stellar photography have not yet been fully realized, and it will require full discussion of the work in hand and to be done, before these can be seen, but judging only by what has already been done, there is a certainty that much valuable data will be accumulated for the astronomer at present and in the future, with very much less labour and in a better manner than by the old methods.

The American Eclipse Expedition to Caroline Island.

The Report of the American expedition to Caroline Island to observe the Total Solar Eclipse of May 6, 1883, has been published

during the past year by the American National Academy of Sciences.

The United States Government having generously undertaken this expedition, placed it under the able direction of Professor E. S. Holden, and the complete and exhaustive character of the Report, as an account of the operations and a history and monograph of this almost unknown island, reflects high credit upon their selection.

The results of the Eclipse observations have already been briefly noticed by the Council.

The volume under consideration commences with an account of the long journey from New York to Caroline Island, a distance of 8000 miles, and back *viâ* San Francisco.

The position of this island, as determined by the expedition is in longitude west of Greenwich $10^h\ 0^m\ 57^s\cdot6 = 150°\ 14'\ 24''$, and latitude 10° 0′ 0″·59 south.

Mr. Winslow Upton contributes an interesting report on the meteorology of the island, including observations of solar radiation made during the Eclipse, to determine what proportion of heat received by the earth was cut off by the concealing of the Sun, and the results are very fully discussed. The instruments used on the day of the Eclipse were conjugate thermometers, Violle's bulbs with black bulb thermometers, and ordinary black and bright bulb thermometers. The conclusions arrived at are that, as the readings of all the instruments were essentially the same at the close of totality, and agreed with the observed air temperature, this indicates that during the total phase no heat was received by the earth from the atmosphere so far as these instruments allowed of its measurement. During the Eclipse the amount of heat gradually diminished until practically none was received, and the temperature of night was attained. In the chart of relative intensity appended, the maximum point of the curve appears to be about four minutes after the first contact; the minimum point is about three minutes after the observed time of third contact, and the second maximum about four minutes after last contact.

The astronomical part of the volume is mainly occupied by Dr. Hasting's account of his spectroscopic observations, which have been noticed in a former Report, and a discussion of the theory of the corona advanced by him. At present his views have not met with acceptance among astronomers.

A report on the Fauna and Flora of this small island, only seven or eight miles long and two or three miles wide, and a full account of its physical geography, make up a monograph of an expedition which in many ways is unique, and was carried out in a most satisfactory manner by Professor Holden.

Professor Langley's Researches on Solar Heat.

During the past year the Signal Service Department of the United States has issued a valuable report, by Professor Langley, on Solar Heat. The Professor has for some years been studying the subject at the Allegheny Observatory with actinometers and his own bolometer, by which he can examine not only the total heat received from the Sun on a surface, but also the amount conveyed by very small portions of the spectrum, and, having arrived at results as to atmospheric absorption somewhat differing from those usually received, he desired to confirm them by experiments under specially favourable circumstances.

Being supplied with funds by the liberality of a private individual, and with the aid and support of the chief and staff of the Signal Service, he resolved to make observations of absorption at the top and bottom of a mountain of considerable height in the southern part of the western States, and, if possible, to select one such that the abruptness of its rise would allow a station at the top to be very close to the one at the bottom, and to seek a clear dry air.

Finally Mount Whitney, in lat. 36° 35′ N., long. 118° 30′ W., was selected, and in the second chapter of his Report he tells the story of his work, involving a journey across a treeless, waterless desert in the heat of July and August. All the projected work did not succeed, but the results confirmed and added to the conclusions he had reached at Allegheny.

He says, "We conclude that the action of our atmosphere is incomparably more complex than ordinary theory assumes it to be, and that even were we provided with a better theory, causes not yet fully understood introduce systematic errors into high and low Sun observations, tending to impair the results of the best observer at one station, and on the whole to lead him to underrate the amount of the absorption.

"We find, as we ascend in the atmosphere, its transmissibility marked by changing, so that on the whole, quite independent of its lessening density, the air becomes more and more transmissible as we directly ascend it. The transmissibility, as determined by actual observation, without the use of any formula, confirms in the most absolute manner, that, with the exception of the cold bands, the transmissibility increases throughout the spectrum when the wave-length increases, the violet being more transmissible than the ultra-violet, the blue than the violet, the green than the blue, the yellow than the green, the red than the yellow, and the border of the dark heat than the red, until, when we have gone farther down in the spectrum, the transmissibility will become almost complete, except for sudden great interruptions of it—the cold bands—the largest of which we discovered on Mount Whitney.

"Finally," he says, "my conclusion is that, in view of the large limits of error, we can adopt three calorics as the probable value of the solar constant; by which I mean that, at the earth's mean distance, in the absence of its absorbing atmosphere, the solar rays would raise one gramme of water 3° Centigrade per minute for each normally exposed square centimetre of its surface.

"Though the actual solar radiation is thus largely increased, yet the temperature of the Earth's surface is not principally due to this direct radiation, but to the quality of selective absorption in our atmosphere, without which the temperature of the soil in our tropics would probably not rise above—200° C.

"Generally speaking, the radiation which we see enter we see escape within the utmost known limits of the spectrum. The heat-storing action from checked re-radiation, to which the surface temperature of this planet is due, apparently goes on beyond these limits, where no spectrum measurements have yet been made. *No such wave-lengths as those belonging to heat radiation from the soil, we believe, have ever entered our atmosphere from the sun*, though we admit their existence in the solar spectrum before absorption. Professor Langley's investigation extends the directly-observed spectrum to a wave-length of nearly $\frac{3}{1000}$ of a millimetre, up to which point he says probably the transmissibility of the spectrum increases, but there it suddenly ceases, as if all beyond were an unlimited cold body."

A paper has also been very recently received, in vol. iii. part 1 of the "Memoirs of the National Academy of Sciences," in which Professor Langley expresses an opinion that the temperature of the sunlit surface of the Moon is not far from the freezing temperature, but not so far below as we might expect to find that of an absolutely airless planet.

Maps of the Spectrum.

During the past year two important maps of the solar spectrum have been completed, the one photographic and the other a carefully executed hand-drawing. The photographic map has been made in the dry air of the United States with one of Professor Rowland's concave gratings of $21\frac{1}{2}$ feet radius and 6 inches diameter. A scale of wave-lengths has been added, so that the whole makes a map of the spectrum extending from wave-length 3680 to 5790: that is, from above H down nearly as far as D. The region in the neighbourhood of H is on four times the scale of Ångström's map; the region at the less refrangible end is on twice the scale, and the intermediate portion is on three times the scale, of Ångström. The definition is so good that 1474, b^3 and b^4 are shown clearly as double lines, and E, though not distinctly split, can be easily recognised as double. The wave-lengths of more than 200 lines in the

spectrum have been accurately determined to about $\frac{1}{500000}$ part, and these serve as standards to correct any small errors of the appended scale.

The hand-drawing of the spectrum has been made by M. Thollon with a large bi-sulphide of carbon spectroscope kept at an even temperature by water circulating within the table on which it is mounted, and also within a metal double-walled box which descends from the ceiling and covers the instrument. The light of the Sun is thrown from a heliostat on to the instrument through a window on one side of the metal box, and the observer looks through a telescope passing through the other side of the box. All adjustments of the instrument can be rapidly made by rods and strings passing through the sides of the box. With this instrument M. Thollon has made a map of the spectrum from A to *b*, more than ten mètres long, carefully distinguishing the atmospheric lines from those of solar origin. Each portion of the spectrum is represented by four bands, the upper one of which represents the solar spectrum as observed when the Sun is at a distance of 80° from the zenith, and the air is neither very dry nor very damp. The second band represents the spectrum as seen when the sun is 60° from the zenith and the air is very damp. The third band represents the spectrum as seen when the sun is 60° from the zenith and the air is very dry. The fourth band contains all the lines of exclusively solar origin, and has been constructed by prolonging the lines which remain unaltered under varying atmospheric conditions.

The observations upon which the drawings are based have been principally made at Nice. M. Thollon has been occupied for more than four years in measuring the positions of the 3200 lines included in his map, and in laying them down, paying special attention to the relative darkness of the lines, their breadth, nebulosity, and other characteristics. It is hoped that steel plates from these valuable drawings will be published in the first volume of the *Annales* of the Observatory of Nice, which M. Bischoffsheim intends to publish in the course of next year.

Longitude Determinations.

The United States Bureau of Navigation, in continuation of former similar work by officers of the U.S. Navy, has published a series of telegraphic longitudes of places in Mexico, Central and South America, determined by an expedition under the command of Lieutenant-Commander C. H. Davis, U.S.N.* The methods pursued were identical with those of the former expeditions and leave nothing to be desired in point of accuracy. The

* "Telegraphic Determinations of Longitudes in Mexico, Central America, and on the West Coast of South America."—Washington, 1885.

idea was "to carry the same system of measurements over the cables of the Mexican and Central and South American Companies and the West Coast of America Company, which extend from Galveston in the United States to Vera Cruz, and from Salina Cruz in Mexico in an unbroken line to Valparaiso in Chili." Captain Davis's instructions included the connection of his chain of measurements with the meridian of the national Argentine Observatory at Cordoba, which was the terminal point of the chain of measurements already made on the east coast of South America; so that they might, "by closing a great polygon of meridian distances, all measured by American astronomers following the same methods, determine a new value for the longitude of the Cordoba Observatory, the degree of whose accordance with the one already found would be a measure of the accuracy of the whole work."

The new determinations are: 1, Vera Cruz, which was connected with Galveston, the longitude of which, from the Washington Observatory, had been previously determined; 2, La Libertad, Salvador; 3, Guatemala; 4, Paita; 5, Arica; 6, Valparaiso; 7, Lima; 8, Cordoba, all of which depend upon Panama, the longitude of which had been determined by Commander Green, U.S.N., in 1875.

The longitude of the Argentine National Observatory at Cordoba derived from this new series is $4^h\ 16^m\ 48^s{\cdot}238$ west of the Royal Observatory, Greenwich, while the longitude of the same Observatory, determined in 1878 and 1879 by the chain measured from Greenwich to Buenos Ayres, was $4^h\ 16^m\ 48^s{\cdot}060$, a difference of $0^s{\cdot}178$, which difference "represents the algebraic sum of the errors of the measurements of all the sides comprising the polygon. The measurements are mostly not corrected for personal equation of the observers. A discussion of them, for an adjustment of the several longitudes, will form the subject of a future paper from the Bureau of Navigation."

After a delay of ten to fifteen years the Government Astronomer at Madras has published * the longitudes measured from Madras Observatory in connection with Lieut. Fleuriais' expedition, 1870; the eclipse of the Sun, 1871; and the transit of *Venus*, 1874. The places are Pondicherry, Singapore, Jaffna, Colombo, Karachi, Muddapur, and Roorkee. The differences of longitude all depend upon exchanges of telegraphic signals, but from the special circumstances of each case, comparisons for the estimation of the relative personal equations of the observers were impossible. For the time observations at Madras the result of the transit of each clock star is given. No allusion is made to the errors of collimation, level, or azimuth, or other instrumental corrections, or to the authority for the R.A.'s of the stars observed. On the other hand the whole of the signals are printed in detail. Except for Pondicherry and Avanashi, no

* "Telegraphic Determinations of the Difference of Longitude, &c."—Madras, 1884.

details whatever are given of the time determinations at the other places. Some of these, however, have been published elsewhere. Considering that only a few hours' labour were necessary to deduce the longitudes from these clock comparisons, and the natural desire of those with whose co-operation and for whom the work was done to obtain the results in reasonable time, the delay in this publication is without a parallel in the history of astronomy; by it the colony of Ceylon has been deprived of the benefit of a good longitude for fourteen years, during which period all the officers who took an interest in the work have either died or left the colony.

A work of quite exceptional character in this branch of astronomy has been recently issued by the Earl of Crawford and Balcarres.* It contains the whole of Mr. Gill's work on the longitudes and latitudes during the private expedition to the Mauritius for the observation of the transit of *Venus*, 1874. The determination of the longitude of Belmont, Mauritius, by the transportation of fifty chronometers from Aden and back, formed a main feature of the expedition. The authors hoped that the most scrupulous attention to the temperature corrections of the chronometers would result in a longitude of Belmont measured from Aden comparable, as regards accuracy, with the only other method available, the lunar. On the outward journey the interval of time which the chronometers had to measure was twenty days; on the homeward journey thirteen days.

During their residence at Mauritius the observers connected their station with that of the British Government on the Island of Rodriguez by the transportation of some fifty chronometers on board H.M.S. *Shearwater* with Mr. Meldrum's Observatory at Pamplemousses, and with the German station at Solitude by telegraph; while on the return journey to Aden connection was made with the Dutch observing station on Réunion, and, with the co-operation of Commander Wharton, a longitude of the Seychelles was obtained. Fully one-half of this large volume is devoted to the telegraphic longitudes of Malta, Alexandria, Suez, Aden, and Bombay, the two first-named by exchange of signals direct with the Berlin Observatory. The longitudes of Alexandria and Suez had been previously obtained by the British Government expedition to Egypt in connection with the transit of *Venus*, by direct signals from Greenwich; and Aden and Bombay have been since re-determined by the officers of the Trigonometrical Survey of India. The differences of the double determinations are in all cases very small, as was to be expected.

This volume, in which everything is printed in the most elaborate detail, is at once a monument to the astonishing energy characterising the work of the principal observer, Mr. Gill, and to the ability and munificence of the noble originator of the enterprise.

* Dun Echt Observatory Publications, Vol. III., 1885.

Papers read before the Society from February 1885 *to February* 1886.

1885.

Mar. 13. On the proposed change of the astronomical day. Professor S. Newcomb.

Note on the track of the total phase in the total Solar Eclipse of 1885, Sept. 18, in its passage across New Zealand. J. R. Hind.

Phenomena of *Jupiter's* satellites and occultations of Stars by the Moon observed at Stonyhurst, 1884. Rev. S. J. Perry.

Account of some physical observations of *Venus* in 1884. A. Stanley Williams.

Solar Eclipses and occultations by the Moon (with diagram of the Solar Eclipse Aug. 28–29, 1884, at Granada, West Indies). Rev. J. Pearson.

On variations in the light of β *Lyræ*. E. von Gothard.

Observations of Barnard's Comet (*b* 1884), made at the Natal Observatory. E. Neison.

On the value of the long inequality in the motion of the Moon, due to the disturbing action of the planet *Mars*. E. Neison.

On the proposed change of the astronomical day. Professor Th. von Oppolzer.

Notes and corrections to Sir John Herschel's synopsis of all Sir William Herschel's measures. H. Sadler.

Jupiter's IVth satellite. E. J. Spitta.

Note on the transit of *Jupiter's* satellite IV., seen at Clapham, 1885, Feb. 27. E. J. Spitta.

Note on the *Nautical Almanac* dimensions of the Saturnian system. Captain W. Noble.

On the right ascensions of the Cape Catalogues for 1850 and 1880. A. M. W. Downing.

On the star places of the *Nautical Almanac*. A. M. W. Downing.

Spectroscopic results for the motions of Stars in the line of sight obtained at the Royal Observatory, Greenwich, in the year 1884, No. VIII.

April 10. Occultations of Stars by the Moon in the years 1876-80, and resulting final equations between the errors of

April 10. the tables and the errors of observation. G. L. Tupman.
The periodicity of Solar Eclipses. Prof. C. V. Zenger.
Occultations observed at Forest Lodge, Maresfield. Captain W. Noble.
Occultation of *Aldebaran*, 1885, February 22, observed at Dun Echt, Aberdeen. Dr. R. Copeland.
Observation of the projection of *Jupiter's* 1st satellite on its own shadow, 1885, February 18, made at Dun Echt, Aberdeen. Dr. R. Copeland.

May 8. Observing weather. Rev. S. J. Johnson.
Five orders of Meteor-streams or Comets. R. A. Proctor.
Total Solar Eclipses visible in the British Isles in the years 878–1724. J. Maguire.
Observations of Comet 1884, III. (Wolf) at Harrow. G. L. Tupman.
A peculiar variety of Meteors. W. F. Denning.
Observations of *Saturn*. N. E. Green.
Note of an observation during the transit of *Jupiter's* satellite IV., 1885, April 18. E. J. Spitta.
On the right ascensions of the Cape Catalogues, 1850, 1860, and 1880. E. J. Stone.
On the diameters of the Sun and Moon as observed with the Greenwich transit-circle. W. G. Thackeray.
Reply to Mr. Stone's paper on screw errors as affecting the N.P.D. of the Cape Catalogue for 1880. David Gill.

June 12. Observations of the satellites of *Saturn* and of the companion of *Sirius* made at the United States Naval Observatory, Washington. Professor A. Hall.
Craters in the Moon. Lieut.-Colonel H. S. Knight.
The velocity of Meteors. W. F. Denning.
Ephemerides of the satellites of *Saturn*, 1885-86. A. Marth.
Ephemeris of the satellite of *Neptune*, 1885-86. A. Marth.
Elliptic elements of Comet 1883, II. (Ross). R. Bryant.
On Al-Sûfi's Star magnitudes. E. B. Knobel.
On daylight occultations of *Aldebaran* in 1885. J. R. Hind.
On some points of difference between the Harvard and Oxford Stellar Photometry No. 1. Prof. C. Pritchard.

Nov. 13. Observations of the companion of *Sirius*, made at the Dearborn Observatory, Chicago. Prof. G. W. Hough.
Observations of Comet, 1884 (Wolf) made at the Royal Observatory, Cape of Good Hope.
Observations of Comet 1884 (I.) (Pons-Brooks), made at the Royal Observatory, Cape of Good Hope.

Nov. 13. Observations of Comet 1884 (II.) (Barnard), made at the Royal Observatory, Cape of Good Hope.

On the application of a Nicol's prism to sextant observations. Captain T. Mackenzie.

The horizontal and vertical diameters of the Sun, as observed with the Greenwich transit-circle. W. G. Thackeray.

Total Solar Eclipses, A.D. 878 to 1724. J. Maguire.

Note on stationary radiant-points. R. A. Proctor.

On the proper motions of the stars L L 31296 and 31188. G. L. Tupman.

Observations of Comet 1885 (Barnard) at Harrow, with the 18½-inch equatorial reflector and ring micrometer. G. L. Tupman.

On a suspected new variable star in *Corona Borealis*. G. F. Chambers.

Ephemeris for physical observations of *Jupiter*, 1885–86. A. Marth.

On Al-Sûfi's and Ptolemy's Catalogues (extract from a letter to Mr. Knobel). Professor Schjellerup.

Daylight occultation of *Aldebaran* on July 9, 1885, observed at Forest Lodge, Maresfield. Capt. W. Noble.

On the reduction of Bessel's precessions to those of Struve. A. A. Rambaut.

Note on Mr. Chambers's suspected new variable in *Corona Borealis*. Rev. T. E. Espin.

Notes on the Total Solar Eclipse of 1885, September 9, viewed at the Terrace, Wellington, New Zealand. C. R. Marten.

Erratic Meteors. B. J. Hopkins.

Ephemeris for physical observations of *Mars*, 1886. A. Marth.

Photometric observations of the Nova in the *Andromeda* nebula, made at the Oxford University Observatory. Professor C. Pritchard.

On Dr. Wilsing's experimental examination of the wedge-photometer; and (II.) on the degree of accuracy attainable by means of that instrument. Professor C. Pritchard.

The outburst in *Andromeda*. Rev. S. J. Perry.

Observations of the spectrum of the new star in the great nebula in *Andromeda*, made at the Royal Observatory, Greenwich. E. W. Maunder.

A new form of governor for the driving clocks of equatorials. A. Hilger.

Proposal for photographing the heavens. (Letter to the President, from Admiral Mouchez.)

Dec. 11. On a suspected new variable star in *Corona Borealis*. J. E. Gore.

Dec. 11. Observations of double stars at Windsor, New South Wales. J. Tebbutt.

The *Andromeda* meteors. J. Rand Capron.

Notes of the Meteorites of Nov. 27, 1885, as seen at East Tisted Rectory, Alton, Hants. Rev. F. Howlett.

On the orbit of γ *Coronæ Australis*. J. E. Gore.

The Meteoric display of 1885, Nov. 27. Col. M. F. Ward.

Meteor shower connected with Biela's Comet. Rev. S. J. Perry.

Occultation of *Uranus* 1885, Dec. 1. Rev. S. J. Johnson.

On the term of long period due to *Mars* in the expression for the longitude of the Moon. E. Neison.

The Meteoric shower as seen at Clapham on the night of Nov. 27, 1885. E. J. Spitta.

Ephemeris for the satellites of *Uranus*, 1886. A. Marth.

The Biela Meteor shower of Nov. 27, 1885. Professor C. Pritchard.

Observations of the Meteor shower of Nov. 27, 1885, made at the Glasgow Observatory. Professor R. Grant.

On the Meteoric shower of Nov. 27, 1885. Dr. R. Copeland.

Observations of Comets Brooks, Fabry, and Barnard made at Dun Echt Observatory with the filar micrometer of the 15-in. refractor. Communicated by Lord Crawford.

La grande pluie des étoiles filantes du 27 Novembre, 1885. F. Denza.

The great shower of *Andromedes* Nov. 26, 27, 28, and 30, 1885. W. F. Denning.

General catalogue of radiant-points of shooting-stars. W. F. Denning.

Observations and orbit of the Meteor shower of 1885, November 27. G. L. Tupman.

Observations of magnitude of *Nova Andromedæ*, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

On the connection between photographic action, the brightness of the luminous object, and the time of exposure as applied to celestial photography. A. C. Ranyard.

Comparison of Groombridge's and Struve's right ascensions of close circumpolar stars. Prof. T. H. Safford.

Jan. 8. Observations of the Biela's Comet meteors, made at the Royal Observatory, Greenwich.

The Meteor shower of 1885, November 27. Major G. Strahan.

Jan. 8. The Meteor shower of 1885, November 27. Major A. C. Bigg-Wither.

On a new spectroscopic method for measuring close double stars. Prof. C. V. Zenger.

Photographic maps of the stars. I. Roberts.

On a new variable star of short period. J. E. Gore.

Observations of Comet 1885 (Brooks) at Harrow with the 18½-inch equatorial reflector. G. L. Tupman.

On the new star in *Orion*. J. E. Gore.

Observations of the Meteors of 1885, November 27, made at the Radcliffe Observatory, Oxford. W. H. Robinson.

Display of Meteors, 1885, November 27. W. Wickham.

Note on the Biela Meteors. R. A. Proctor.

Ephemeris of the satellites of *Mars* 1886. A. Marth.

On the variation in colour of the *Nova Andromedæ*, and on the evidence it affords as to the origin of the *Nova*. B. J. Hopkins.

Note on Mr. Marth's "Intersects." H. H. Turner.

On a new star in the constellation of *Orion*. Dr. R. Copeland.

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1885, and a comparison of the results with the tabular places from Hansen's Lunar Tables. E. J. Stone.

Note on the Transit of the planet *Mars* and its satellites across the Sun's disk, which will occur for the planet *Jupiter* and its satellites on April 13, 1886. A. Marth.

Changes in the red spot on *Jupiter*. W. F. Denning.

Spectroscopic results for the motions of stars in the line of sight obtained at the Royal Observatory, Greenwich, in the year 1885, No. IX.

Observations of Comets *d* 1885 (Fabry) and *e* 1885 (Barnard), made at the Royal Observatory, Greenwich.

Observations of occultations of stars and *Uranus* by the Moon and of phenomena of *Jupiter's* satellites made at the Royal Observatory, Greenwich, in the year 1885.

Observations of the spectrum of *Nova Andromedæ*, made at the Royal Observatory, Greenwich. E. W. Maunder.

On photographs of a new nebula in the *Pleiades*, and of *Saturn*. (Letter to the President, from M. Henry.)

List of Public Institutions and of Persons who have contributed to the Library, &c. since the last Anniversary.

Her Majesty's Government.
Her Majesty's Government in Australia.
Her Majesty's Government in India.
The Lords Commissioners of the Admiralty.
The Norwegian Government.
British Association for the Advancement of Science.
British Horological Institute.
Geological Society of London.
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Hamilton Association.
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Hong Kong Observatory.
Leipzig, Astronomische Gesellschaft.
Leipzig, Royal Society of Sciences of Saxony.
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Melbourne, Patent Office.
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Moncalieri Observatory.
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Montreal Geological Survey.
Montreal, Royal Society of Canada.
Munich, Royal Bavarian Academy of Sciences.
Munich, Royal Observatory.
Natal Observatory.
Neuchatel, Society of Natural Sciences.
New Haven, Connecticut Academy.
New York, Columbia College.
Paris, Academy of Sciences.
Paris, Bureau des Longitudes.
Paris, Dépôt Général de la Marine.
Paris, École Polytechnique.
Paris, International Committee of Weights and Measures.
Paris, Mathematical Society of France.
Paris Observatory.
Paris, Philomathic Society of France.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
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Pulkowa Observatory.
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Rome, Italian Spectroscopic Society.
Rome, Pontifical Academy dei Lincei.
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St. Petersburg, Imperial Academy of Sciences.
San Fernando Observatory.
Stockholm Observatory.
Stockholm, Royal Swedish Academy of Sciences.
Sydney, Government Observatory.
Tacubaya Observatory, Mexico.
Tasmania, Royal Society.
Tiflis, Physical Observatory.
Tokio University.
Toronto, Canadian Institute.
Toulouse, Academy of Sciences.
Trieste, Imperial Nautical Academy.
Turin, Italian Meteorological Society.
Turin, Observatory of the Royal University.
Turin, Royal Academy of Sciences.
Upsala, Royal Society of Sciences.
Vienna, Imperial Academy of Sciences.
Washington, Bureau of Navigation.
Washington, Office of the American Ephemeris.
Washington, National Academy of Sciences.
Washington, Smithsonian Institution.
Washington, United States Chief Signal Office.
Washington, United States Coast and Geodetic Survey.
Washington, United States Naval Observatory.
Yale College Observatory.

Yokohama, Seismological Society of Japan.
Zurich, Central Meteorological Institute.
Zurich, Society of Natural History.
Zurich, Swiss Geodetic Commission.
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Prof. C. A. Young.

ADDRESS

Delivered by the President, Edwin Dunkin, F.R.S., on presenting the Gold Medal of the Society to Professor Edward C. Pickering, For. Assoc. R.A.S., and Professor Charles Pritchard, D.D., F.R.S.

Gentlemen,

The Council have awarded the Gold Medal conjointly to Prof. Edward C. Pickering, Director of the Observatory of Harvard College, U.S., and the Rev. Charles Pritchard, D.D., Savilian Professor of Astronomy in the University of Oxford, for their "Photometric Researches." It now devolves upon me, as your President, to explain generally the grounds upon which this award is based.

You may remember that in June, 1871, a new bye-law was enacted by the Society, on the recommendation of the Council, to authorise the award of a joint Medal when it appears expedient to recognise the independent researches of two or more persons who have been working independently on the same subject, and who at about the same time have announced publicly the results of their separate labours. In past years much inconvenience has been experienced for want of such a power on the part of the Council, though on one occasion in 1867 means were found to justify the award of a joint Medal. But in this case the recipients were co-workers, and the Fellows, with enthusiasm, condoned that somewhat irregular act of the Council, which apparently was a departure from a course which the bye-laws had prescribed. On inspecting the new bye-law, enacted in 1871, it will be perceived that the Council are now authorised to receive the nomination of two or more persons as joint recipients of the Medal, provided that the nominees are the simultaneous, but independent, authors of any treatise, work, research, or discovery; and the bye-law goes on to say that "should the Medal be ultimately awarded to such joint authors, workers, or discoverers, an impression of the Medal shall be provided for and given to each of such joint recipients." The Council have therefore great pleasure in carrying out, for the first time, the terms of this new bye-law, by their award recognising the important and interesting stellar researches independently carried on by Profs. Pritchard and Pickering, as a comparatively

new subject of physical inquiry, combining new principles and apparatus in the investigation.

Since the appointment of Prof. Pickering to the superintendence of the Observatory of Harvard College he has devoted much time and attention to the subject of the comparative lustre of the stars, the results of which have from time to time been communicated to astronomers. The magnitude of his work on the photometry of the stars was not, however, realised till the appearance in 1884 of the first part of Vol. XIV. of the *Annals of the Astronomical Observatory of Harvard College*, which includes the results of his photometric examination of all stars of the sixth magnitude to 30° south declination. This great work contains chapters giving a detailed description, with diagrams, of the meridian photometer used in the investigation; a summary of the whole series of observations, including a discussion of the estimated magnitudes of *Polaris*, the star to which all other stars were referred; notes on the atmospheric absorption of light; on eye-estimations of the brightness of the stars, visible to the unaided eye, for comparison with the corresponding photometric determinations; and a general catalogue giving in tabular form the main results of the entire investigation. The number of stars included in the catalogue is 4,260, representing 700 series of observations, and 94,476 separate comparisons made between October 25, 1879, and September 17, 1882. The list contains all the stars not fainter than the sixth magnitude between the North Pole and 30° south declination, or as low as stars can be conveniently observed for this purpose in latitude 42° N. The stars were selected from several standard catalogues, in which the magnitude is given as, at least, the sixth. They have all been observed near the meridian, where they have the greatest altitude, thus facilitating the computation of the correction for atmospheric absorption. A second part of the work appeared in 1885, consisting mainly of a detailed discussion and comparison of all the original star-magnitudes found in various original catalogues, from Ptolemy and Al Sûfi to modern times, and it is a discussion of some magnitude, exhibiting in its compilation the results of great zeal and research. In addition to this comparison, the second part includes separate chapters on discordant observations, suspected variables, the distribution of stars, and other subjects.

The instrument devised by Prof. Pickering, and which appears to have been perfectly successful, has been named by him the Meridian-Photometer. It consists of a horizontal telescope pointing to the west, having two similar object-glasses of about four centimetres aperture and 80 centimetres focal length. Right-angled prisms are placed in front of the object-glasses, through which the images of the stars to be measured and the comparison star, *Polaris*, are reflected. The prism through which *Polaris* is reflected may be turned by rods around two axes, one perpendicular to the axis of the telescope, the

other coinciding with it. By these two motions *Polaris* may always be brought into any part of the field of view. The prism which reflects the star to be measured may also be turned around the axis of the telescope, and it carries a graduated circle, divided into degrees, the index of which is so adjusted as to give the declination of the star reflected. This prism can also be inclined by means of a screw so as to vary the collimation if required. A further technical detail of the photometer I give strictly in Prof. Pickering's own words: "The use of two objectives might be expected to produce two separate emergent pencils. Errors would then be caused by a slight movement of the eye of the observer, a portion of one pencil being sometimes cut off by the edge of the pupil. Moreover, we cannot be sure that different portions of the eye are equally transparent. Different pencils would likewise pass through different portions of the eyepiece, and would be unequally reduced by the dust upon its surfaces. To avoid these various sources of error, the double-image prism is placed near the focus of the objectives. This prism is made of Iceland spar compensated by glass. Each pencil is thus divided into two. The northern of the two pencils from the southern objective is made to coincide with the southern of the two northern pencils. This is effected by varying the angles of the spar and glass prism. As the prisms are cemented together, the interval between the two images may be varied by grinding the face of the spar, while a change in the glass face moves both images together. Two or three trials sufficed to make the two central pencils coincide, and pass nearly through the centre of the eyepiece. In front of the latter is placed a Nicol. An eye-stop has an aperture of such a size that it will admit the central pencils and cut off the two outside pencils. By placing this stop a little excentrically, the slight deviation of the pencils in traversing the Nicol was corrected. The pencils forming the images to be compared are therefore coincident, and are formed by precisely similar object-glasses. A graduated circle, divided into degrees, is attached to the eyepiece and Nicol, and on turning it through any angle from the point where one image disappears, the light of that image will evidently be proportional to the square of the sine of the angle. An index serves to measure this angle in degrees and tenths." Some difficulty was at first experienced from the imperfection of the annealing of the reflecting prisms, but this was overcome by a method of local correction, by which a better definition of the images was obtained. Great credit is due to Prof. Pickering for devising the meridian photometer, which in his hands has been so successful; for though it may be considered in some respects an adaptation of previously existing photometers, there can be no question as to the fact that he has introduced so many important modifications that makes it, in reality, a new and original instrument.

Prof. Pickering had the aid of a large staff of assistants dur-

ing the three years occupied by these observations. The following is a brief sketch of the daily routine of work. To observe with the meridian-photometer two persons are required. The image of *Polaris* is first brought by the observer into the middle of the field of view, by the two handles moving the northern prism. An assistant, who records the observation, then, by means of the declination-circle, directs the southern prism to the star to be measured, which is brought into the middle of the field by the collimating screw. "The observer places the image of the Pole-star near that of the star to be measured and makes a setting by turning the Nicol until the images appear to be equal. He then notifies the recorder to enter the reading, which is done to tenths of a degree. On being notified by the recorder that the reading has been made, he turns the Nicol so that the image of the Pole-star just disappears and then regains a brightness equal to that of the other star. This second setting is recorded while the observer reverses the images by moving the northern prism. Two more settings are then made in the same way as before." It was usual to call the work of each observer on a single evening by a distinguishing number or series. Each series was limited to about an hour, the observations being continuous, one star being brought into the field as soon as the preceding star had been measured. By limiting a series to an hour, any injurious effect arising from the fatigue of the eye was diminished.

The success of the meridian-photometer in the investigation before us induced Prof. Pickering to construct a larger instrument of improved form, with which he has been enabled to observe the photometric magnitudes of Neptune, some of the minor planets, and objects generally not fainter than the tenth magnitude. The object-glasses are about four inches aperture and sixty inches focal length, and the instrument differs from the smaller one in many of the details. In his report of the work of the Harvard Observatory from 1877 to 1882, Prof. Pickering states that he intends to employ this larger photometer "in the revision of the stars of the northern heavens where the zones of the various observatories overlap by a small amount. Over eight thousand stars are contained in these overlapping portions. The light of all these stars is to be determined with it, and the estimates of light of the various observers in the entire work of revision may thus be reduced to a single standard. Besides this work, the standard stars of the *Uranometria Argentina*, the comparison stars for variables, and other objects of interest will be measured."

In a more recent report, Prof. Pickering states that the observations with the new meridian-photometer have been regularly continued, and in some measure extended. During the year 1885 more than two hundred series of observations were made, representing upwards of fifty thousand separate settings, or nearly double the number made in the preceding

year. The accordance of the results continues satisfactory, the average deviation of the separate measures of the standard circumpolar stars being about ·12 of a magnitude. In order to increase the regularity of distribution of the stars observed, other zones of 20′ in width have been added to those previously selected for observation, so that the entire series now includes zones at intervals of five degrees from the equator to the pole.

In some instances Prof. Pickering has adopted the wedge-photometer for the determination of the photometric magnitudes of the fainter class of objects, as in the revision of the magnitudes in the *Durchmusterung*; faint stars selected as standards of magnitude in twenty-four regions following bright stars; and also stars which have been used as standards of comparison for variable stars. When these comparison stars are of sufficient brightness, they have been usually measured by the meridian photometer, and their magnitudes, thus determined, serve as a basis for the measurement of the fainter stars by the wedge-photometer. "Two observations of each star not determined by the meridian-photometer, and of a sufficient number of the others, are made with the wedge on each evening when the region occupied by the comparison stars of any particular variable is observed. Two complete observations of this kind, made on different evenings, are regarded as sufficient; but when moonlight or other causes render the work of either evening imperfect, it is repeated on a third evening." Prof. Pickering does not consider that the wedge-photometer employed at the Harvard Observatory is capable of the great degree of precision claimed for the Oxford photometer, and in order to ascertain whether this difference is due to the form of the instrument, he has requested Prof. Pritchard to superintend the construction of a wedge-photometer, upon the same plan as that at Oxford, for use at the Harvard Observatory. This instrument is now completed by Mr. Hilger, and is, or soon will be, in the hands of Prof. Pickering.

For the determination of the law of atmospheric absorption, Prof. Pickering selected 100 of the brighter stars, none being fainter than the sixth magnitude, between 60° and 75° north declination, some of which were observed on each evening at their upper and others at their lower culmination. A table is given showing the observed magnitude of each star, from which the adopted coefficient of absorption has been determined to be ·250. The diminution of brightness at the lower culmination indicates to what extent the magnitude of the star is affected by the atmosphere.

It is impossible, in the brief time at my disposal, to do full justice to Prof. Pickering's excellent work, and consequently I must reluctantly pass over many points of interest worthy of attention, and confine my remarks for a few minutes to the general catalogue of results containing all the main details of the investigation. The system of abbreviation, once understood, is

a great convenience, as it increases the space for the insertion of more facts and references. The catalogue, as I have already stated, contains the fullest particulars relating to the photometric observation of 4,260 stars. A mere glance at its crowded columns, extending over 173 pages, is sufficient evidence of the magnitude of the undertaking, the produce of only three years' observation, and less than two years' subsequent computation and research. The catalogue gives the names of the constellations; the designating letters and numbers in various standard catalogues; the approximate right ascensions and declinations for 1880; the eye-estimated magnitudes according to the *Uranometria Nova*, the *Atlas Cœlestis Novus*, the *Durchmusterung*, and the *Uranometria Argentina*; the photometric measures and probable errors; the number of the series; the residuals in tenths of a magnitude, obtained by subtracting the mean photometric magnitude from the separate results of the photometric measures; the corresponding residuals of the separate direct estimated magnitudes; and the results of no less than fourteen series of estimates of antecedent astronomers, commencing with Ptolemy, compared with the mean photometric magnitudes, the residuals being expressed in the same form as for the direct estimations. These former estimates have been reduced to one uniform scale by a method explained by Prof. Pickering.

In April 1879, a circular was issued from the Harvard Observatory, in which was suggested the employment of certain stars very near the North Pole as photometric standards of stellar magnitude. In connection with this proposal, seven stars, sufficiently bright, were observed for this purpose. Four of these—*Polaris*, δ *Ursæ Minoris*, *Cephei* 51, and λ *Ursæ Minoris*—are included in the general catalogue, the photometric magnitudes of the remaining three being 6·5, 8·0, and 8·8 respectively. Omitting *Polaris*, from fourteen to seven measures of each star were obtained with a mean probable error of ·04. The photometric measures of twenty-six stars in the *Pleiades* group have also been made and compared with the eye-estimations of Bessel, Argelander, C. Wolf, Pritchard, and Lindemann. The residuals are no greater than might have been expected, those of Pritchard and Lindemann being very small. These are only a few of many other miscellaneous series of photometric observations undertaken by Prof. Pickering, to which my limited time will not permit me to allude. I may, however, again remark that stars known to have been used as standards of comparison for variable stars, especially those employed by Argelander, Schönfeld, and Oudemans, have been observed with the meridian-photometer as far as practicable. He has also successfully applied the principle of polarisation of light to the photometry of double stars.

It has struck me very forcibly, while examining the columns of residuals in the general catalogue, that the average deviations from the mean are in most cases within reasonable limits; yet

in many instances they are considerable, far exceeding what we might expect in an observation of this kind. Possibly, in a few cases, the wrong object has been observed, though Prof. Pickering remarks that this could not frequently have been done, as there were several checks adopted to assist in the identification of the object. There may be other causes for the large deviations, such as the varying effects of atmospheric absorption produced by mist or unobserved passing clouds, and sometimes from the rapidity with which the observations were made. As a rule, however, the effect of these apparently large discordances, amounting occasionally to a whole magnitude, is probably for the most part eliminated in the mean result.

With regard to the accidental errors contained in the catalogue, Prof. Pickering remarks that ten series of observations of *Polaris*, the photometric magnitude of which he has assumed to be 2·15, were made in order to determine the accordance of successive comparisons made in the same part of the photometric circle. He found the mean discordance of the ten results to be just one-tenth of a magnitude, thus making the corresponding average deviation of the mean of four comparisons ·05. This quantity he assumes to be the average deviation of one set when the comparisons are made at the same part of the circle, or near the same time. Prof. Pickering has also found that the average deviation of one set of four comparisons, at the upper culmination, between *Polaris* and one of the standard circumpolar stars is ·16, and as the mean of the probable errors of the photometric magnitudes determined from all the stars in the catalogue is ·072, and the average number of observations 4·4, the corresponding average deviation is also ·16, thus agreeing with the value obtained from the circumpolar stars alone. Prof. Pickering considers that this deviation of ·16 is due to various causes, the effect of some of which may be separately determined. He has, consequently, deduced an average deviation of ·11, which he attributes to the combination of several causes, such as changes in the instrument or the eye; personal equation between the observers; the uncertainty of the instrumental correction determined from the three observations of *Polaris*; and from the neglect of hundredths of a magnitude in the original computations. He also considers that additional causes may be found in "the variations in the transparency of the atmosphere, actual variations in the light of the stars, undetected errors in identifying the object observed, and mistakes in recording the observations."

Comparing the Harvard results with those of Sir John Herschel's northern and southern sequences, we find the respective differences are ·09 and ·16; with Argelander's magnitudes ·18, with Westphal's ·26, and with Zöllner's ·12. The differences between the Harvard photometric magnitudes of the larger stars in the *Pleiades* and the corresponding values determined by Prof. Pritchard and Lindemann are ·09 and ·14

respectively, and for certain stars compared with variables by Argelander and Schönfeld, ·11 each. Taking 179 stars common to the catalogues of Seidel, Wolff, and the Harvard photometric catalogue, it is found that Harvard differs from Seidel by ·200, and from Wolff by ·120, while Seidel and Wolff differ by ·201. Hence the average deviations of the three catalogues are respectively ·18, ·09, and ·09. These results are in accordance with those found by other methods, and they tend to increase our confidence in the resulting photometric magnitudes of all the separate stars contained in this magnificent contribution to stellar astronomy, with which the name of Prof. Pickering will in future be honourably associated.

It is now time to refer to the corresponding investigation carried on at the University Observatory at Oxford during the last four years, under the able direction of Prof. Pritchard. I believe that I am correct in saying that at the commencement of the observations he was unaware of the methods and intentions of Prof. Pickering, with respect to the system of photometric observations pursued at the Harvard Observatory. Prof. Pritchard's primary object in selecting this branch of research as a fitting one for the new Observatory was the conviction that here an interesting field of inquiry, hitherto to some extent neglected, was open to him. We must, therefore, for our present purpose consider the two investigations as strictly independent and original, and as such they are both recognised by the Council in their award of a joint Medal.

At the meeting of the Society on November 11, 1881, Prof. Pritchard described a simple and practicable method of measuring with considerable accuracy the relative apparent magnitudes of the stars, by means of a new photometer which he had devised, since known as the "wedge-photometer." He, however, claimed no novelty as to the particular implements employed, but only as to the definite methods of applying them and of reducing the results. He had at that time made a photometric comparison of about fifty stars, by which he was assured that far greater precision could be attained in the relative differences of magnitude than by any system of eye-estimation. On May 11, 1883, Prof. Pritchard presented a more elaborate memoir to the Society, entitled, "Photometric Determinations of the relative Brightness of the Brighter Stars North of the Equator" (*Memoirs of the Roy. Astron. Soc.* vol. xlvii.), containing a description of the wedge-photometer, the system of observation, and a statement of the results obtained to the date of publication. The memoir also contains a most interesting historical epitome of all that had been previously accomplished by others in this interesting branch of astronomy, both in the determinations of star magnitudes by photometers of various constructions and also by eye-estimation. The general methods adopted by preceding observers, especially those of Sir William Herschel, Sir John Herschel, and Argelander, are discussed, and the whole

chapter gives a very general notion of the history of the subject. Besides a full explanation of the theory and use of the wedge-photometer, this memoir also includes a photometric determination of the value of the constant of absorption produced by the atmosphere, and notes on the measurement and magnitude of coloured stars, and on the variation of the amount of the extinction of light due to the varying altitude of the star. Although in the Oxford observations the curves graphically representing the variations of brilliancy of the same star at different altitudes were not altogether satisfactory to Prof. Pritchard, he observes that "they did in general represent variations proceeding in accordance with some law, and were fairly consistent until the zenith distance exceeded 60°, but beyond that distance the results were sometimes discordant, and not seldom apparently lawless." So important and essential to his inquiry did Prof. Pritchard consider an accurate knowledge of the value of the absorption constant, that, with his accustomed vigour, he resolved to compare the results of the observations made at Oxford with others determined with the same instrument and observer in some climate steadier and more uniform than that at Oxford. Accordingly, in January and February 1883, we find him, with his assistant, Mr. Jenkins, stationed at the Khedive's Observatory, near Cairo, prosecuting his research with such success that, after a residence of five weeks, no fewer than 3,385 wedge extinctions were made. The absorption constant determined at the two stations, though indicating a real difference of climate, differed less than had been anticipated, the respective values from the Oxford and Cairo extinctions being ·253 and ·187, or ·066 of a magnitude—a quantity about equal to the probable error of an observation with the photometer employed. It may be remarked that Prof. Langley on Mount Etna found the coefficient of absorption to be ·126, Müller at Potsdam ·209, Bouguer in Brittany ·225, and Seidel and Pickering ·250. The corresponding photometric magnitudes determined at Oxford and Cairo are given in the memoir. The measures included in this preliminary synopsis of results are confined to stars brighter than the fifth magnitude of Argelander's scale, and the adopted values are all zenithal magnitudes, the comparison having been made assuming the zenithal magnitude of *Polaris* to be 2·05. The corresponding magnitudes from the catalogues of Ptolemy, Al Sûfi, Argelander, Houzeau, and Gould are inserted for comparison.

This memoir and other shorter communications on the subject have been followed by a more complete work, *Uranometria Nova Oxoniensis*, containing the results of all Prof. Pritchard's photometric observations. Among other kindred works on photometry, this collection of results must take a prominent place, and it will assuredly rank as a standard treatise on the subject, as a reliable exposition of the relative photometric magnitudes of the principal stars visible to ordinary and unaided

eyes from the North Pole to about ten degrees south of the Equator. For the sake of accuracy, I extract from the introduction to this volume Prof. Pritchard's explanation of the construction of the wedge-photometer, with which all his observations have been made. "The wedge-photometer, as employed at Oxford, is a wedge of very nearly neutral tinted glass, $6\frac{1}{2}$ inches long, 1 inch broad, and ·145 inch thick, tapering off to ·02 inch. Cemented to it is a similar wedge of white glass, placed the reverse way; the whole forming a rectangular prism. This glass prism, or *wedge*, is inclosed in a brass cellular rim with bevelled edges, one of which is divided into tenths of inches, the divisions being distinct and white for visibility at night. It slides in a groove on the brass cap of the eyepiece of any telescope, close to the achromatic eye-lens, and is thus placed between the eye of the observer and the telescope. In the focus of the eye-lens is a diaphragm, pierced with a number of small holes, which vary from the hundredth of an inch to a quarter of an inch in diameter, and in which small circular hole the telescope image of a star is carefully placed, and there viewed through the wedge. Further, the eye of the observer is directed along the axis of the lens and of the telescope by means of an external eye-hole, placed close to the wedge, and varying from one-twelfth of an inch to a quarter of an inch. This direction of vision is important. A fiducial mark is drawn on the brass cap of the eyepiece, so that the position of the wedge can be distinctly marked and recorded when the image of the star is just extinguished by the wedge. Usually the position of the wedge, when the light of the star is just extinguished, is observed five times, and the mean of all the five readings is called the *wedge reading*. The extinction of a second star is then observed in a similar manner, and the difference between the two wedge readings is called the *wedge interval*."

It has been customary at Oxford to select about ten stars for one night's work, at nearly the same altitude as the comparison star *Polaris*, so that any correction to the measures for absorption may be avoided. Two telescopes were employed, one of four, the other of three inches aperture, to which photometers were respectively attached. These telescopes being in separate domes, the two observers were each instructed to measure the specified stars independently, taking the precaution to observe the extinction of *Polaris* at the beginning, the middle, and the end of the series. The extinctions of the comparison star were observed five times with the full aperture of the two telescopes, and five times after reducing the aperture to one-half by placing a cap on each object-glass. Thus a check on the first set of five measures was established by means of virtually a new instrument. Then four independent sets of five extinctions were made of each star to be measured, making altogether twenty extinctions. It will thus be perceived that the observations were made in an orderly and systematic manner, and with much simplicity. This

appears to me one of the advantages to be attained by the use of the wedge-photometer.

Prof. Pritchard has ascertained from a special comparison of the means of five extinctions of about twenty stars, made by Mr. W. E. Plummer and Mr. Jenkins, each observing with different apertures the same stars as nearly as possible in point of time, and with the same wedge and telescope, that there is practically no sensible difference of personal equation between the two observers, and that therefore they might safely interchange the instruments without introducing any systematic error in the results.

The 2,784 stars selected for observation are those contained in the *Uranometria Nova* from the North Pole to 10° south of the Equator. The limit of magnitude is therefore Argelander's sixth. In the catalogue the stars are arranged alphabetically in the order of constellations, the separate columns giving the approximate R.A. and N.P.D. for 1890, the adopted zenithal magnitude assuming that of *Polaris* to be 2·05, the average deviation in magnitude, the date of observation, and the corresponding magnitude in the *Uranometria Nova*. Copious notes are given, in which the concluded results for stars observed both at Oxford and Cairo are inserted. We have in this catalogue the relative magnitudes of most of the principal stars visible in the northern hemisphere determined with great precision from upwards of seventy thousand separate extinctions. When we remember that the University Observatory was established under many difficulties, that the observing staff consists of only two assistants, and that during six months of the year much time is given to lecture work and practical instruction to the undergraduates at night, we have strong grounds for giving all the credit that is due to those by whose energy and zeal so much good and standard work has been accomplished since the foundation of this Observatory in 1875.

It is not my desire or intention to make any critical comparison of the results obtained by the wedge-photometer with those derived from other sources. This will probably be done by others at the proper time, and in a more formal manner. But the question naturally arises, are the results obtained by the wedge-photometer to be accepted as fairly accurate representations of the relative stellar magnitudes? Prof. Pritchard considers that they are, as a whole, sensibly accurate to the tenth of a magnitude, and if the probable error be any indication of accuracy, I think he has reasonable grounds for his belief. We have had lately several important discussions at the meetings of the Society on the capabilities of the wedge-photometer, besides other criticisms. Some of these are valuable, especially those of Dr. Wilsing in the *Astronomische Nachrichten*, No. 2,680, but at the same time I believe that the explanations given by Prof. Pritchard in answer to these criticisms have practically smoothed down many of the difficulties pointed out, thus minimising the

effect of some of the systematic errors to which this form of photometer may be liable. Most probably the results derived from every kind of photometer are affected more or less with systematic discordances. I believe there can be no doubt upon this point. But if the deviations from the mean result afford any evidence of the steadiness of observing, it is certainly shown to great advantage in the Oxford observations, though it has been asserted, and not without reason, that the small differences of deviation from the mean is a sign of the want of sensitiveness in the instrument. May we not rather attribute this general agreement partly to the comparatively simple character of the observation, and to the care and attention of the observers? I have been very much impressed on this point by the apparent uniformity exhibited in the tables communicated by Prof. Pritchard to the Society in November last (*Monthly Notices*, vol. xlvi. p. 9), consisting of several nights' repetition of the determinations of the magnitude of sixteen selected stars. These observations were made under different circumstances as regards the condition of the air and the observer. Only in one isolated instance does the difference between the greatest and least daily results exceed four-tenths of a magnitude, while the average deviation from the mean of each of the sixteen stars varies only from ·03 to ·09, or equal to an average deviation of ·06. Referring to the smallness of the discordances, Prof. Pritchard says: "The final results, so far as my powers of scrutiny extend, exhibit no symptoms of systematic error. The average deviation from the mean for all these repeated observations on so many nights still remains approximately the same as for stars measured in the normal manner on a single fair night, viz. about ·06 magnitude; and this, I think, represents in reality the utmost average delicacy attainable with the wedge-photometer, and I claim for it an accuracy at least as great as has been yet attained by any other instrument."

Perhaps it may be considered, and I think very properly so, that one conceivable source of error in the measurement of such minute variations of light might arise from the natural fatigue of the eye during a long series of observations. In order to ascertain whether any error of this kind exists in the Oxford photometric measures, Prof. Pritchard made a special examination of a large number of extinctions of *Polaris* made on separate nights at the beginning, the middle, and the end of each series, from which he appears to be satisfied that there are no real grounds for supposing that any sensible variation in the method of observing, due to fatigue of the eye, takes place during the three hours occupied in making the observations on any one night. From my own personal experience of the ordinary fatigues of a long night's observation with the Greenwich transit-circle, occasionally extending in the winter months over a watch of nine or ten hours, I have invariably found that though at the end of the observations the body may be very

wearied, the eye has usually retained its full sensitiveness, and able to distinguish the faintest objects visible in the telescope equally as well as in the earlier part of the evening. I attribute this apparent retention of acuteness of vision after a long and fatiguing night's work, chiefly to the relief obtained by an occasional rest from observing during the watch, and to the variable work which the eye is called upon to perform during the intervals of actual observation at the telescope. Prof. Pritchard has evidently a similar experience with regard to the Oxford observers, as he finds that any undue strain on the eye is probably compensated by the "relief afforded by continual breaks in the work of actual observation, connected with the shifting of the domes, with the identification of the stars, and with the recording the results." The circumstances of the two cases are not, however, strictly analogous.

It may be a matter of interest to some if I refer to the general agreement existing among the deduced magnitudes of a large proportion of the stars north of the equator common to the Harvard and Oxford catalogues. From a comparison made recently, it is found that the accordances within one-tenth of a magnitude are 31 per cent., within one quarter of a magnitude 71 per cent., and within one-third of a magnitude 95 per cent., leaving only 5 per cent. of discordances exceeding one-third of a magnitude, many of which may be accounted for on reference to the notes. Viewed in this light, and considering that the magnitudes are determined by photometers constructed on totally different principles, we must admit that this general and substantial agreement between the results of the two independent researches is very remarkable, and indicative of a great step having been accomplished towards an accurate knowledge of the relative lustre of the stars.

And now, gentlemen, I have laid before you a short summary of the reasons by which your Council have been guided in the award of a joint Medal for the subject of stellar photometry. In thus recognising the labours of Profs. Pritchard and Pickering, they are glad to acknowledge, at the earliest opportunity, the systematic zeal and devotion displayed by each in the prosecution of their important researches, carried on with an energy which claims our admiration. In Prof. Pritchard we observe an astronomer whose opportunities for stated Observatory work only commenced at a time of life when most of us naturally feel a desire to be relieved from all active research, establishing under difficulties a first-class Observatory, which has already attained a reputation for sound original work, of which many older establishments might well be proud—a reputation that, doubtless, will be retained at least so long as the University Observatory remains under the personal control of our esteemed colleague. We must all congratulate him on the complete success of his labours, in the energetic prosecution of which he has shown himself to be a worthy successor of the long roll of distinguished

Savilian Professors who have preceded him, many of whom are known as honoured and illustrious astronomers, whose investigations form a large portion of the past history of our science. The continuous devotion of Prof. Pickering to astronomical research has also gained for him universal esteem and regard among his associates in astronomy on both sides of the Atlantic, as one of our most original and active inquirers, not only in this branch of the science, the consideration of which has occupied our attention to-day, but also in other important fields of stellar research. By the award of the Medal he is only receiving a due acknowledgment of his valuable services, and a token of the desire of the Council to express their full appreciation of the scientific value of the numerous contributions he has made to astronomy.

The President, on delivering the Medal to Prof. Pritchard and the Foreign Secretary, addressed them respectively in the following terms :—

Professor Pritchard,—

I have very great pleasure in presenting this Medal, which the Council have awarded to you conjointly with Prof. Pickering. I hope you will accept it as an acknowledgment on their part of the excellent work you have accomplished during your superintendence of the University Observatory at Oxford. I assure you that the important contribution you have made to astronomy on the relative magnitudes of the stars is highly appreciated by the Fellows, and I trust that you may still be spared many years to continue your valuable researches.

Dr. Huggins,—

In forwarding this Medal to Prof. Pickering, I would request you to inform him that the Council entertain the highest opinion on the merits of the important research on which he has been engaged, and for which they have had much pleasure in awarding to him this Medal conjointly with Prof. Pritchard. I trust that what he has so successfully accomplished is only the prelude of further researches, and thus add still more to the great astronomical reputation he has already achieved.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President.

J. W. L. Glaisher, Esq., M.A., F.R.S.

Vice-Presidents.

J. C. Adams, Esq., M.A., LL.D., D.C.L., F.R.S., Lowndean Professor of Astronomy, Cambridge.
W. H. M. Christie, Esq., M.A., F.R.S., Astronomer Royal.
The Earl of Crawford and Balcarres, F.R.S.
Edwin Dunkin, Esq., F.R.S.

Treasurer.

A. A. Common, Esq., F.R.S.

Secretaries.

E. B. Knobel, Esq.
Lieut.-Col. G. L. Tupman, R.M.A.

Foreign Secretary.

William Huggins, Esq., LL.D., D.C.L., F.R.S.

Council.

J. Rand Capron, Esq.
Arthur Cayley, Esq., M.A., LL.D., D.C.L., F.R.S., Sadlerian Professor of Pure Mathematics, Cambridge.
G. F. Chambers, Esq.
A. M. W. Downing, Esq., M.A.
J. R. Hind, Esq., LL.D., F.R.S., Superintendent of the *Nautical Almanac*.
George Knott, Esq., LL.B.
E. W. Maunder, Esq.
Capt. William Noble.
Rev. Charles Pritchard, D.D., F.R.S., Savilian Professor of Astronomy, Oxford.
A. Cowper Ranyard, Esq., M.A.
E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.
Lieut.-Gen. J. F. Tennant, R.E., F.R.S.